Trends in drug distribution and medication safety

Hadewig B B Colen, PharmD, PhD; Robert Janknegt, PharmD, PhD

THE STRIDES THAT HAVE BEEN MADE IN COMPUTER TECHNOLOGY HAVE REVERBERATIONS THROUGHOUT THE PHARMACY WORLD. THIS EJHP SPECIAL EDITION CONTAINS A WEALTH OF INFORMATION ON THE WAYS THAT THE NEW TECHNOLOGY, WHEN APPLIED TO DRUG DISTRIBUTION SYSTEMS, IS HELPING IMPROVE THE RECORD ON MEDICATION SAFETY. THE SPECIAL EDITION IS INTRODUCED BY OUR GUEST EDITORS, DR HADEWIG COLEN AND DR ROBERT JANKNEGT.

Drug distribution is one of the key processes in hospitals. The process involves the continuum of prescribing, reviewing, preparing, dispensing and administering drugs. The physician prescribes a drug in a certain dosage in the name of the patient to support his treatment; the pharmacist checks the information and sends a definitive medication order in the patient's name to the nursing unit. A nurse will administer the drug to the patient on the basis of this definitive order and register that she has done so. The pharmaceutical industry renders the drug identifiable by labelling drug packaging with the drug name, strength, batch and expiry date.

The material flow is initiated by the medication order. Drugs are purchased from the pharmaceutical industry or wholesaler, transported to the pharmacy, where they are stored and then delivered to the ward or patient. The drug may be dispensed in either the central pharmacy or the nursing unit. When the drug is administered, the patient and drug information is coupled and registered.

We know from error studies and experience that there are many problems with administration techniques associated with labelling and packaging. We also know that drugs are taken away for other purposes, e.g. borrowed to give to another patient or even stolen, and some of them can not be administered because they have expired. Moreover, stress, chronically understaffed nursing units, lack of appropriate training and poor communication may induce medication errors when drugs are dispensed manually [1, 2].

There are only a few controlled studies that show improvement of medication safety after implementing an automated dispensing machine ADM [3]. Studies on the effects of ADMs on medication error rates and cost effectiveness compared with traditional systems are inconclusive. It is not easy to compare these studies because of differences in distribution systems, variability in linkage to other information systems and methods of data collection. Overall, ADMs alone have the least support for their effectiveness in preventing medication errors. However, implementation of new technology in the drug distribution process necessitates a complete redesign of services and considerable financial requirements. Therefore, novel technology in this area should have proven benefits on medication safety and a complete evaluation of appropriateness before broad implementation can be recommended. Development of a standard evaluation model using performance indicators is necessary to compare available ADMs with regard to performance, cost-effectiveness, and prevention of medication errors and enhancement of safety [4].

Objectives

This special supplement discusses various logistic systems that support the drug distribution process in hospitals. The focus of the articles is on the location in the logistic system where ADMs may be used to reduce medication errors.

The idea for the supplement was born during a trip by a group of Dutch hospital pharmacists to several hospitals in the US (in Boston, St Petersburg, Pittsburgh, Chattanooga, Nashville, Madison) for a study of the performance of the various distribution systems that they use.

The following stages in drug distribution have been studied to work out the objectives, more or less in the order of the medication process in hospitals:

- Pharmacy: centralised ADMs, summarised by Dr Hans Harting and co-workers on page 50
- Physician: computerised physician order entry described by Dr Frank Rynja and co-workers page 52
- Hospital ward: direct delivery by the wholesaler to the hospital ward (Dr Pieter Knoester et al., page 63) and unit-based cabinets (Eric Haak et al., page 56)
- Drug administration: bedside assortment picking (Krijn Dekens et al., page 69), bar-coding (Monique van der Westerlaken et al., page 60) and a closed loop system (Professor Irene Krämer and co-workers, page 66)

Finally, the supplement concludes with an overview of the existing options by Dr Hadewig Colen et al., on page 71.

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Centralised automated drug dispensing systems

Yvonne Dijstelbloem-de Jong, PharmD; Hans W Harting, PharmD; Andre W H Krings, PharmD

IN THIS ARTICLE, THE AUTHORS DISCUSS THE VARIETY OF CENTRALISED AUTOMATED DRUG DISPENSING SYSTEMS NOW AVAILABLE AND THE PART THEY PLAY IN REDUCING MEDICATION ERRORS.

In 1999 the Committee on Quality of Health Care in the US published the report "*To Err is Human*", which highlighted the fact that medication errors cause over 7,000 deaths per year and result in adverse effects in 2% of hospital inpatients. The report also suggested that medication errors increased the cost of each hospital stay by $4,700 (€3,708), resulting in an annual cost of billions of dollars if these values are extrapolated to the entire country [1–3].

Medication errors occur in prescribing, transcribing, dispensing, preparation and administration.

To reduce medication errors many different solutions have been proposed. In this article the use of centralised pharmacy automated dispensing machines (ADMs) is discussed.

There are two types of ADM: the solid oral medicine (tablets and capsules) dispensing systems manufactured by Baxter FDS, Dijkstra de Vereenigde JV and Tosho, and the total concept dispensing systems that can dispense different formulations, e.g. oral, ampoules and suppositories that are manufactured by Swisslog and McKesson. However, the McKesson Robot Rx is not available in Europe.

In Table 1 the main properties of the two different systems are summarised.

In The Netherlands, the use of solid oral dispensing systems is common, especially for nursing homes. For use in hospitals a total concept dispensing robot is much preferred. The number of total concept dispensing systems used worldwide is low.

In Table 2 a comparison between the two available total concept dispensing systems is shown.

The advantages of ADMs are:

- Lowering of labour costs in pharmacies and on the ward
- Fewer dispensing errors
- Less expired medicine because of improved inventory management
- Lower inventory costs because of needing less stock on the wards
- Medicine is bar-coded to make bedside verification possible (point of care bar-code scanning)
- Eliminates medicine easily in case of recall
- Cuts medications missing on the wards
- Less medicine wasted

Application of drug distribution robots in the hospital pharmacy setting

In this article we have focused on robots, which can distribute all kinds of dosage forms. This is in contrast to automatic tablet counters (ATCs), which can only distribute solid oral dosage forms.

In The Netherlands, almost all hospital pharmacies use drugs in unit doses, to be able to register the administration of the drug to the patient by bar-code technology. This means that almost all drugs have to be repacked in unit doses before they can be distributed per patient by the robot. The choice is now narrowed down to the

Table 1: Properties of ADMs, more information can be obtained from individual manufacturers [4–8]

	Oral dispensing systems	Total concept dispensing systems
Medicine form	Tablets, capsules	Tablets, capsules, patches, ampoules, suppositories, vials, pre-filled syringes, unit dose cups
Number of different medicines	Up to 520	Up to 4,400 (on average 2,700)
Total number of medicines	Not available (dependent on tablet size and number of canisters)	Up to 44,400 (on average 27,000)
Loading and dispensing at the same time	No	Yes
Output capacity	Maximum of 60 pouches/min unit-dose Maximum of 50 pouches/min multi-dose	See Table 2
Return of unused medicines	No	Yes
Bar-code facilities	Yes	Yes

Table 2: Comparison between the two available total concept dispensing systems [4, 5]

	McKesson Robot Rx	Swisslog Pillpicker
Maximum storage capacity	25,000 unit doses	44,000 unit doses (on average 27,000 unit doses)
Different forms of medicine	Not available	4,400 (on average 2,700)
Way of dispensing	In cassettes or in envelopes	In cassettes or patient-specific rings
Bar code	Yes	Yes
Output capacity	Not available	600–1,000 bags with medication/hour (with patient-specific rings)
Return of unused medicine	Yes	Yes
Prevention of dispensing expired medicine	Yes	Yes

McKesson robot and the Swisslog because the Exper Homerus has been taken off the market and the Next-Rx robot will no longer be developed. However, as mentioned earlier, the McKesson robot system is not available in Europe. In the US these robots are used to restock the wards or satellite pharmacies as well as for drug distribution per patient per 24 hours.

If we are looking at the use of the drug distribution robot to restock the wards or the satellite pharmacies we should also look at the robots which are being used in retail pharmacy, such as the Rowa machine. With these machines it is possible to restock ward pharmacies with boxes containing 50 tablets in unit doses or, for instance, ampoules. These robots, which are being used on a large scale throughout Europe, are much cheaper and the total number of users guarantees adequate support from the manufacturer.

Quality assurance of automated dispensing

The introduction of ADMs in hospital pharmacy requires focus on quality protection and validation; dispensing errors can lead to consequences for a large number of patients. Many hospital pharmacies fail to carry out a risk analysis before implementation of ADMs. Initial validation of the system as well as software validation is often lacking or incomplete [9].

An important element in quality assurance is the permanent monitoring of errors. Registration and analysis of errors must lead to implementation of measurements to improve the quality of output. There are two methods to collect information on the achievements of ADMs: spontaneous reporting of errors by users of the system, or self-performed output validation. Spontaneous, voluntary reporting of errors results in underestimation of the total amount of errors in comparison with self-performed checks of system output [10, 11]. This implies that voluntary reporting of errors is not an optimal indicator to determine the achievements of ADMs. Periodical validation of the total process of automated dispensing is, in our opinion, essential to ensure and improve the quality of output.

A critical step in the process of automated dispensing is refilling of the canisters. Because of the serial character of the process, filling a canister with the wrong drug could result in widespread distribution of this drug. Most ADMs contain calibrated canisters to prevent such errors from taking place. However, smaller units often fit through the calibrated opening of the canister. Double visual identity checks are time consuming and often inadequate. Bar-code checks are a safe method to ensure concordance between stock and canister content. Stock units without bar codes must be labelled under GMP conditions [9].

After every process affecting intervention (maintenance, repair, placing of a new canister), accidental machine errors could occur. Revalidation of the system by performing a 'blank run' is a necessary aspect in quality assurance.

Registration of essential proceedings during the process of automated dispensing is vital for reconstruction of procedures and release of the batches produced. Registration of proceedings can be accomplished by filling out a 'daily operating form'. This form contains information on the orders produced, the quality and safety checks performed, the machine errors identified as well as maintenance information. The form can also function as a formal document for the release of batches [9].

Management of software authorisations is a critical aspect in quality assurance of ADMs. Without adequate management of user charges, system settings could be changed unintentionally. User authorisations should therefore be limited and management of permissions should rest on a minimum number of employees [9].

Automated dispensing is a complex process and quality protection is difficult. It is essential to minimise machine errors, thereby minimising patient risks. In the interest of the patient, it is necessary to use observed errors to enhance medication safety and optimise the quality of the distribution process.

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Computerised physician order entry (CPOE) in The Netherlands

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MEDICATION SAFETY IS A TOPIC OF WORLDWIDE INTEREST. AS A RESULT, IMPLEMENTATION OF COMPUTERISED PHYSICIAN ORDER ENTRY (CPOE) IS BEING ENCOURAGED INCREASINGLY AS AN IMPORTANT SOLUTION TO THE CHALLENGE OF REDUCING MEDICATION ERRORS. IN THIS ARTICLE THE AUTHORS DESCRIBE THE DUTCH EXPERIENCE.

The Dutch Society of Hospital Pharmacists (NVZA) has made medication safety the main item on its agenda since 2000. The use of CPOE systems is not yet widespread in The Netherlands. A nationwide survey in 2004 revealed that only 7% of hospitals use CPOE completely [1]. However, implementation is planned to start as a pilot in another 41% of hospitals. In this article we elaborate on issues of CPOE and the available systems in The Netherlands.

CPOE systems

CPOE is a computer application that allows physicians to enter orders for patient prescriptions, rather than — usually in illegible writing — on paper [see Panel 1]. This alone would amount to nothing more than simple work flow automation, but CPOE goes well beyond replacing paper orders with electronic ones. It compares new orders against standards for dosing, checks for allergies or interactions with other drugs, and flags potential problems. Thus, CPOE makes relevant information available at the time of ordering and ideally, applies rules-based logic to help the physician make optimal ordering decisions.

Panel 1: Advantages of CPOE systems compared with paper-based systems [7, 12]
Completeness of order
No handwriting or interpretation errors
No transcription errors
Enables on-line decision support
Integrated in medical record
Identification of ordering physician
Aid for training and education
Usable source for research and analysis
Cost reduction (formulary, over-prescribing)

When examining CPOE systems, it is necessary to differentiate between basic products that focus on capture and transmission of the order ("order communication") and true CPOE systems that contain interactive clinical decision support (CDS). Table 1 shows the basic characteristics of the CPOE systems available on the Dutch market. All of the emerging CPOE systems are in an advanced state of development, and vendors have already identified initial implementation sites. Critical "must-have" CPOE features such as interaction checking and rules-based clinical decision support will ensure improvements in medication safety and quality, as well as enhance ease of use and implementation.

Many CPOE systems have integrated drug safety alerts. One study reveals that drug safety alerts are overridden by clinicians in 49% to 96% of cases [2]. Consequently, as shown in another study [3], patients might get their medicines at a time when they interact with other drugs. This can cause therapy to fail. To prevent such a situation, hospital pharmacists must play an active role in educating physicians to handle drug interaction alerts correctly. Often, overriding of alerts may be justified, and adverse drug events, because of overridden alerts, are not always preventable. In the configuration of CPOE systems, a distinction between appropriate and useful alerts should be made.

A proportion of the current CPOE systems have some sort of integration with an electronic medication administration record (eMAR) and related work flow for nurses and other clinicians. It will also mean that nurses will be able to see the patients' records, prescriptions and dosing instructions each time a medicine is given. Ideally, a CPOE system is part of a fully integrated electronic medication system from start to finish, linking CPOE, pharmacy dispensing and eMAR in one seamless electronic medication administration system as part of the electronic patient record (EPR).

Beyond features and functions, CPOE needs to be highly responsive — exhibiting quick response time to speed physician ordering sessions — and reliable, to support the critical ordering process without interruption. If an application is built for the web, as opposed to existing applications becoming web-enabled, it lowers the total cost of ownership because of the ability to push out technology changes or upgrades quickly without having to load software in multiple locations.

Choosing the right CPOE solution for a hospital requires thinking about many features beyond CDS, and many trade-offs involving implementation, technology, cost and risk. In the end, the organisational challenges are greater than the technology challenges. Thus, the task of selecting the CPOE solution, though necessary, is only the beginning.

Implementation: keys to success

A number of studies have demonstrated that CPOE can reduce medication errors [3]. Only a few hospitals in The Netherlands are using CPOE. Barriers include the state of commercially-available CPOE systems and issues of implementation of these systems [4].

Successful implementation of a CPOE system starts with a vision, shared by top level management, hospital pharmacists and a good part of the clinicians, of the benefits of such a system prevailing over the costs and, short term, implementation issues. The benefits of CPOE are not only the potential to reduce medication errors, but also a reduction of costs, a decrease of hospital stay and an improvement of compliance with treatment guidelines.

The degree to which CPOE integrates with other hospital applications, such as laboratories, pharmacy, EPR and other clinical systems, and benefits the healthcare providers, is key to its success.

Last but not least of the issues that determines success or failure for a CPOE system is the technology of the application, and training and support during implementation and use. Online help and direct assistance by support staff as well as a programme of continuous improvement will guarantee successful use of the system in the long run.

Technology

In the early 1990s the first CPOE systems in The Netherlands were character-based applications that ran from a dedicated computer terminal connected to the hospital information system or from a general-purpose desktop PC provided with terminal emulation software. Although the user-friendliness of those character-based applications was poor they have been used successfully for many years and, as an exception, some still are. The next generation of CPOE systems was graphical Windows-based applications that also offered extended CDS, among other features, resulting from improved ability to connect databases. Examples include connections to laboratory databases or access to reference information guides. In today's clinical practice, the personal digital assistant (PDA) is increasingly used as a mobile electronic source of information.

This results in a growing demand from users for a CPOE application which can run from a PDA. Actual products and implementations are still an exception, mainly because of the limited size of the PDA screen requiring either many user actions because of data being divided over several screens or resulting in illegible and unclear screen information. A better option could be the use of a tablet PC, a lightweight notebook- or slate-shaped mobile computer with a touch screen that is wireless connected to the hospital information system. A particular commercially available mobile solution is a so-called COW (computer on wheels), a portable computer usually with a dedicated task or set of tasks, fitted on top of a specially designed robust frame on wheels.

In general, wireless communication sets additional requirements on data security. This applies to both secure (wireless) data transfer as well as to privacy of patient data. No patient data should remain on the mobile device after logging out because mobile devices are prone to theft.

Clinical decision support systems (CDSS)

Decision support is considered to be a key component of CPOE and may also reduce medication error rates [5, 6]. It can be defined as any information added by a system to assist the clinician's decision-making process. This includes:

- reference materials (e.g. textbooks, journals, medication guides)
- 'expert systems' that assist in diagnosis (e.g. clinical decision rules)
- rule-based systems that provide clinical alerts (e.g. drug-allergy and drug-drug interaction checking)
- scoring systems (e.g. mortality or infection scores)
- data tags that add context (e.g. adding an "L" for low next to a laboratory value)
- systems that assist in therapeutic decisions (e.g. automatic suggestion for insulin and glucose in case of a hyperkalaemic patient)
- computer-based implementations of clinical pathways that facilitate and standardise entry of diagnostic and therapeutic orders
- algorithms and tools to enhance physician efficiency and patient satisfaction

All modern CPOE applications in The Netherlands provide basic clinical decision support including suggestions or default values for drug doses, administration routes and dosing frequencies. Most of them can also perform more sophisticated CDS such as drug allergy checks, drug-laboratory value checks, drug-drug interaction checks, providing reminders about corollary orders (e.g. prompting the user to order glucose checks after prescribing insulin) or drug guidelines to the physician at the time of drug ordering (Table 1). Many checks are done as a synchronous event in the order-entry process. An interface to the laboratory systems, allowing use of diagnostic laboratory values by the decision support system, is important. Also, integration with the clinical information system is essential for getting clinical alerts as a warning of allergy, because allergies are usually documented in the clinical information system and not directly in the CPOE application database.

Many CPOE systems have dosing calculators. However the net effect of CPOE can still be too slow for physicians [6].

Table 1: Basic characteristics of CPOE systems available in The Netherlands

Product	Theriak	Klinicom	Centrasys/ EVS	Medicator	CS-Medicatie
Vendor	TM Software	HI-systems	iSoft	iSoft	Chipsoft
Number of hospitals, that have CPOE in project (or fully operational), 2004 [1]	4 (0)	13 (0)	2 (0)	9 (5)	2 (0)
Pharmacy information system	Theriak	Zamicom	Centrasys ZA	Apotheek	CS-Apotheek, still in development
Electronic medication administration registration (eMAR) integration	Yes	Yes	Still in development	Still in development	Yes
Decision support:					
Check on overdosage, interaction, duplicate medication, contra-indications	Yes	Yes	Yes	Yes	Yes
Standardised orders and treatment protocols	Yes	Yes	Yes	Yes	Yes
Links to reference guides	No	No	No	No	No
Expert system/rule- based DSS	No	No	No	No	No
Integration of other clinical data	No	No	No	Yes	No
CPOE in ambulatory setting	Yes	In test	Still in development	Limited	In test
CPOE integrated in the clinical information system	No	Yes	No	Yes	Yes

For acceptance by the physicians it is important that each institution can modify the decision rules and alerts to fit specific local and role-based needs.

Introduction of new errors

CPOE systems are recommended for achieving and improving medication safety. Much has been published showing that use of a CPOE-system reduces errors [5, 7–11]. However, physicians and pharmacists must also be aware of errors that these systems cause in addition to errors that they prevent [9, 12–13]. Errors fall into two main categories. First are those made when entering and retrieving information, and second, those in the communication and coordination process that the CPOE is supposed to support [14].

Some recently published articles indicate potentially unforeseen problems and call for great care in system design and implementation. It is important to be aware of the impact of introducing a CPOE system on the total medication process and the cultural change issues in the complex critical care environments of a modern hospital. Implementing CPOE requires major behavioural changes [12, 14–16].

The Dutch perspective

The first report of a fully implemented CPOE application in The Netherlands dates from 2003 [17], although in some hospitals, electronic order entry had been in use for some time. Applications used were home-grown. This first report describes the implementation of the iSoft Medicator system in the Academic Medical Centre, Amsterdam, in the period 1997–2001. Despite all the advantages of using CPOE, in the early years of implementation the use of more time-consuming character-based software, and the lack of good (wireless) access to computers were mentioned as disadvantages. Another problem described is the lack of an electronic drug accountability system, making the use of printers necessary.

In 2004 an appraisal reported the implementation of the same type of CPOE in two Dutch hospitals [18]. While introduction was successful in one, it failed in the other, making it clear that implementation of CPOE is an organisational change where social and technical aspects are closely interrelated. After these first reports, the use of CPOE has become more widespread and will continue to grow.

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Pharmacy drug distribution redesign:

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IN THIS REPORT, THE AUTHORS DESCRIBE HOW UNIT-BASED CABINETS (UBCS) ARE CONTRIBUTING TO PATIENT SAFETY AND A STREAMLINED HOSPITAL PHARMACY SERVICE IN THE NETHERLANDS.

The publication of the report *To Err is Human: Building a Safer Health System* [1] was the trigger for many hospitals worldwide to have a close look at the status of their patient safety. Medication was one of the most important issues concerning patient safety. Several reports and recommendations [2–4] were published resulting in a more important role for healthcare information technology and robotics.

To decrease the rate of medication errors, computerised physician order entry (CPOE), robotics, automated distribution devices and bar-code technology have been introduced to support the medicines management process. Some wards in Dutch and Belgian hospitals are equipped with an automated distribution device. In this article we will discuss some aspects of the implementation of automated, computer-controlled, decentralised, medicine storage and distribution devices known as unit-based cabinets (UBCs) [2].

Currently, many Dutch hospitals face such problems as the lack of accurate management information to improve control on rising costs. In addition, shortage of capable personnel has to be addressed, pharmaceutical care has to be improved, medication errors must be minimised and pharmaceutical staff and nurse workload should be reduced by improving efficiency and introduction of supply chain management. Part of the solution for these problems can be achieved by the use of automated storage and distribution devices. The ASHP national survey 2005 [3] can be seen as evidence for this statement. The percentage of US hospitals employing UBCs for decentralised storage and drug distribution increased from 58% (2002) to 72% (2005). In hospitals with 400 beds or more, this percentage is even greater than 92%. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) also contributes to this increasing percentage because these systems must meet its standards. In revisions to the Comprehensive Accreditation Manual for Hospitals that became effective on 1 July 2006, the rationale for the revision of Medication Management Standard MM.2.20 [4] states:

Appropriate medication storage increases patient safety. Medication storage is designed to assist in maintaining medication integrity; promote the availability of medications when needed, minimise the risk of medication diversion and reduce potential dispensing errors.

The main goals for the use of UBCs are improvement of quality, reduction of medication errors and improvement of supply chain management.

UBCs – a brief description

At the moment there are three providers of UBCs on the European market: Medstation from the Pyxis Products division of Cardinal Health [5], OmniRx manufactured by Omnicell [6], and the Dispenser E-lock cabinet from Vanas NV [7].

In general UBCs are modular systems. UBCs can be used as a stand-alone system or as part of an integrated medicine distribution system to store, dispense and track controlled substances, ward stock medication, first dose, scheduled and 'when required' (as needed) medicines. Some cabinets are developed to act as both a medicine distribution system and a medical supply system (Figure 1). The entire cabinet can be divided into several zones; access to each zone can be restricted to authorised persons.

Figure 1: Main dispensing cabinet (pharmacy) with attached auxiliary cabinets (medical supplies) in the Department of Respiratory Medicine, Onze Lieve Vrouwe Gasthuis Hospital (Omnicell configuration)

THE ROLE OF UNIT-BASED CABINETS

Andre W H Krings, PharmD

The device consists of a main dispensing cabinet with a colour touch-screen monitor. Auxiliary cabinets can be attached to the main cabinet for additional storage. Some items need to be refrigerated. Other items are too large to be stored in a UBC. Dispensing these items can still be controlled; refrigerators can be equipped with an electronic lock, other items can be defined as remote items. Use of the system is restricted and password- protected.

In Dutch hospitals, medication orders are also reviewed, though there are differences compared with the US. UBC-profiling interfaces with the Dutch CPOE systems and hospital pharmacy information systems are not available yet and need to be developed. This is why the nurse, after selecting a patient, gets access to all of the medicines stored in the UBC. Using the touch screen she can select the medicine either by generic name or brand name. After all the medicines for an individual patient are selected, the system automatically unlocks the appropriate drawers one by one.

Some UBCs are equipped with a light-guided system: light-emitting diodes showing the position of the right drug in the matrix drawer (see Figure 2). Such a system minimises the risk of taking out the wrong drug provided guidelines for correct restocking or returning medication to the UBC are met. Once the amount removed from the UBC is confirmed, the screen displays the next drug and the next drawer is unlocked. Each transaction can be traced back to the nurse and the individual patient for whom the medicine is intended.

For each drug, par, minimum and critical levels are defined for each UBC. If a minimum or critical level is reached, the system automatically generates a replenishment order. Restocking can be done periodically. Supplemental restocks often happen daily, especially for drugs that have reached a critically low level. The pharmacy department is responsible for maintaining the optimum levels (par, minimum and critical).

Special attention has to be paid to the restocking process. This is a critical process because the identification (ID) of the drug is partly defined by its location in the UBC. Restocking is based on (electronic) reports and interfacing with the central pharmacy system. Every replenishment order can be uniquely identified by an ID-code. Before restocking, this ID-code has to be entered on the UBC console. The drugs to be restocked are sequentially listed on the screen, the drawers are automatically unlocked and, if present, the light-guided system indicates where the medicine has to be put.

Figure 2: Matrix drawer equipped with a light-guided system (arrows indicate position of light-emitting diodes). Omnicell configuration, Department of Respiratory Medicine, OLVG Hospital

Some vendors offer additional safeguards. Using bar-code scanning, both the identity of the medicine and the bin location is confirmed ensuring that the right item is in the right location. This interactive restocking process leads to a safe restocking. The first-in, first-out principle can be met in small matrix drawers or in single drug access drawers.

Interfacing

Most UBCs can operate in a stand-alone configuration. A network configuration, where automation systems interface with each other, is to be preferred. The lack of standardisation on 'plug and play' interfaces (and sometimes interface protocols) often results in custom-made and expensive interfaces. Interfacing the electronic order management process and exchange of patient information (admission, discharge and transfer) is mandatory to meet the objectives of implementing a computerised medicine storage and dispensing system. Additional interfaces offer UBC server updates on drug items (e.g. brand names, generic names, par levels, minimum and critical levels) and automatic assignment of drugs to storage bin locations. There is an urgent need for an interface with Dutch CPOE systems (profiling interface), especially if UBCs are located on the wards.

System administration should be carried

out by pharmacy staff because correct operation of UBC systems heavily relies on trouble-free interface operation. Server maintenance and maintenance of the necessary IT infrastructure is the domain of the IT department.

Benefits

Several studies on the added value of UBCs have been published. UBC technology, pharmacy automation and other (hospital) information systems can be integrated. The net result is a contribution to the improvement of patient and medication safety.

Inventory management of medication and medical supplies can be integrated (depending on the configuration), so nurses are confronted with only one user interface.

By means of extensive reporting capabilities, information can be obtained to improve supply chain management. Reports can also be used for compliance and productivity monitoring, cost accounting, transaction review and system optimisation.

The introduction of UBCs results in a reduction of inventory. Once the system is optimised, inventory turnover is increased and waste because of expired drugs can be minimised. Automation of routine tasks improves efficiency and reduces workload of both nursing and pharmacy staff (see Figures 3 and 4). Pharmacy and nursing time required for creating a repeat medication order, documentation on controlled substances and trial medicines can be reduced. Electronic records management also ensures compliance with good clinical practice, good distribution practice and other standards and regulations. Nurses can spend more time with patients. In general terms, nurses are satisfied, even happy, with this kind of technology.

In terms of cost control and charging, everything can be accounted for; revenues should rise because access for authorised users only and logging of all data prevent possible misuse.

Once the loop on the medication use process is closed the system offers a safe way of keeping goods in consignment. This might be an interesting option that can be considered for expensive medicines, expensive diagnostics (e.g. point-of-care tests) or expensive medical supplies.

Figure 3: Order process before UBC implementation (OLVG Hospital)

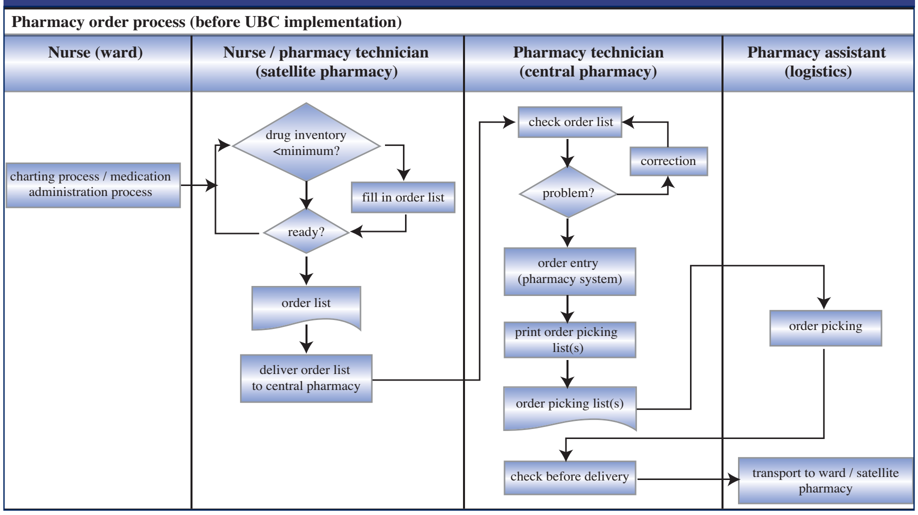
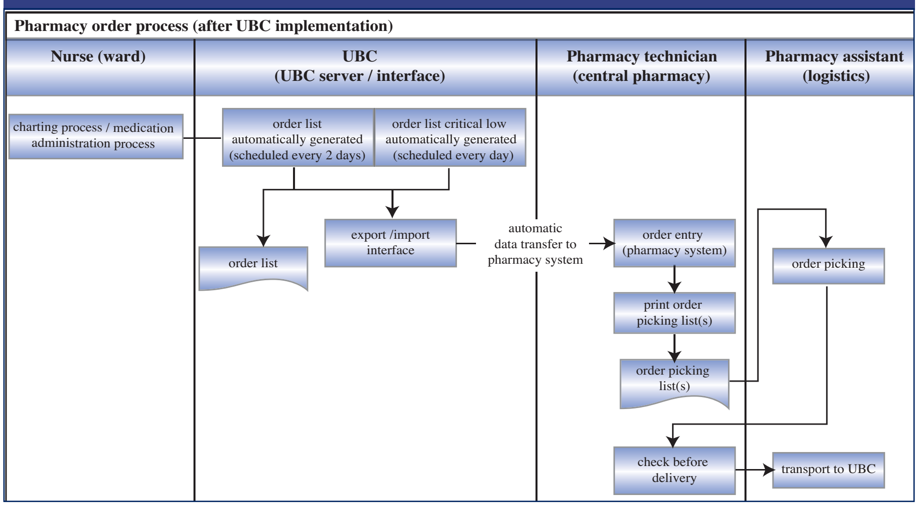


Figure 4: Order process after UBC implementation (OLVG Hospital)



Disadvantages

Implementing new technology can be difficult. Acceptance by nursing staff and even doctors can be an issue. Therefore, a multidisciplinary approach is preferred in which all personnel involved should receive adequate education and training, initially and on an ongoing basis. Standard operating procedures must be updated regularly and, in case of a hospital-wide implementation, the system needs constant monitoring. Suboptimal configuration, poor inventory management and incorrect use may lead to drugs being out of stock; this situation is a safety issue and must be prevented at all times.

Discrepancies can occur and have to be resolved; this can be quite time consuming. The use of matrix drawers seems to be more prone to the development of discrepancies than mini drawers or single drug access drawers [8]. It is important that all involved personnel complies with the standard operating procedures. It can be difficult to maintain the first-in, first-out principle. Poor inventory management can lead to expired stock.

US and European regulations and guidelines are different. Therefore US software has to be adapted to European standards; this can be difficult to achieve.

The system relies heavily on continuity of information. In case of emergencies such as prolonged power or system failure, it may be necessary to unlock the UBC manually. In such situations, changes in inventory have to be processed manually while the system is down. Some patients may not be listed on the UBC console. The system should support manual input of patient data by nursing staff. Afterwards, data have to be reconciled with data originating from the central hospital information system in order to get the system in balance again. Deployment of extra personnel would be needed for system administration and maintenance, and material management.

Some nurses say that working with UBCs is time-consuming. Several patients may take the same medicine but nurses still have to enter patients, one at a time, into the system. Sometimes nurses have to wait for each other to gain access.

Challenges

Implementation of the profiling interface is mandatory in contributing to the improvement of medication and patient safety [9]. This means the (partial) implementation of "the closed loop solution". Introduction of CPOE and medication administration records is the way to create an information continuum that serves as a cornerstone of continuity of care.

Because of the lack of good zero measurements and quantitative objectives, no European studies on the improvement of patient safety, cost-effectiveness and return on investment have been published yet.

Conclusion

The implementation of UBCs improves supply chain management and enhances pharmacy services. The potential to improve medication safety is dependent on the way this technology is embedded in the medicines management process. Future outcome studies have to show whether this technology is cost-effective and improves patient safety.

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Using bar codes in medicine distribution and administration

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BAR CODES HAVE BEEN PART OF THE SUPERMARKET SCENE FOR SOME TIME NOW. IT IS ONLY IN RECENT YEARS THAT THE TECHNOLOGY HAS BEEN REFINED FOR PHARMACY USE. IN THIS ARTICLE, THE AUTHORS DESCRIBE BAR-CODE USE AND HOW IT CONTRIBUTES TO PATIENT SAFETY.

In 2005 the Institute for Safe Medication Practices (ISMP) published an editorial about bar-coding experiences in the US [1]. It stated that since the Institute of Medicine (IOM) published its report, *To Err is Human: Building a Safer Health System* [2] in 1999 and *Crossing the quality chasm* in 2001 [3], hospitals have increased their focus on the prevention of medication errors by adapting new technologies. Bar-coding is one of the technologies that is an efficient method of preventing medication errors by machine-enabled identification of medicines before administration to the patient, a so-called bar-coded enabled point-of-care system (BPOC). In one adverse drug event prevention study, Leape et al. showed that 38% of errors occur at the point of care during administration [4]. Only 2% of administration errors were intercepted. Not all errors were harmful to the patient, but about 7% of administration errors could lead to a potential adverse drug event [5].

Up to 2003, bar-coding had only additional value in logistic processes, but there was no hard evidence that bar-coding technology attributed significantly to reduce relevant medication administration errors [6]. The latter was only recently proven by others who showed error reductions up to 87% [7–9].

The position in the US and Europe

In February 2004 the US Food and Drug Administration approved the Bar Code Rule [10, 11] requiring certain human drug and biological products to have on their labels a linear bar code that contains, at least, the drug's identification number (GTIN). Unfortunately, this has now resulted in more multi-dose packages instead of more bar codes on unit doses.

Europe has no legislation on bar-coding human drugs. Nonetheless, GS1 (formerly EAN International) has established the European Healthcare Initiative to develop the adoption and use of the GS1 system of item identification, bar coding symbols and electronic commerce message standards in the healthcare sector in Europe [12]. The GS1 system is already widely used in European health care across all segments of the market. The data carrier, i.e. the bar code, can be chosen out of a predefined set of possibilities. Apart from this, the European Federation of Pharmaceutical Industries and Associations has worked out an initiative on bar-coding stating that the data matrix bar code is the best solution. However, in Europe, many unit doses still have no bar code at all. European hospital pharmacists have not yet issued a common statement. This will be further complicated by the different opinions on unit dose between the continent and the UK, because the latter, increasingly, is delivering multi-dose packages to inpatients to provide seamless pharmaceutical care.

Unit doses have been widely used in Dutch hospital pharmacy for many years. Dutch hospital pharmacists want to have bar codes on all unit doses, including ampoules etc, at the point of care, for the sake of patient safety. This has resulted in a new statement from the Association of Dutch Hospital Pharmacists asking that labelling of all unit doses, not just tablets and capsules, should be completed with a bar code in agreement with GS1. At this stage, hospital pharmacists are researching further specifications for the required bar codes. The next step is to get these requirements into the contracts with suppliers; this pressure is necessary to get bar codes at the point of care on every unit dose. The German Association of Hospital Pharmacists has adopted the Dutch statement on unit doses and bar codes.

Types of bar codes

Bar codes are sequences of numbers that are machine-readable. Since there are many ways to compose bar codes, standardisation is important. Standardised datasets and data formats can be found in a central data pool with non-commercial article data controlled by GS1 (EAN-Data Alignment Service (EAN-DAS). There are several specified GS1 (EAN) codes. The EAN 13-code is merely for identification and is called an article code or a global trade item number (GTIN). EAN 128 has space for information on the expiry date and lot number. Each kind of information has a prefix or indicator which defines what kind

Figure 1: A representation of the three different parts of a bar code and its content

Indicator	GTIN of the items contained (without check digit)												Check Digit
N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}

of information follows: GTIN, company, country, expiry date and so forth. Some bar codes have an internal check to verify whether or not the bar code is read correctly.

The GS1 system provides several types of bar codes for use by GS1 members depending on the application. This variation is necessary because different bar-code types have different strengths and weaknesses, GS1 selects the bar code that best fits the application. The bar codes used by GS1 include EAN/UPC, Reduced Space Symbology (RSS), GS1-128, ITF-14, Data Matrix, and Composite Component. The one-dimensional bar codes have the advantage of simple technology and equipment but are relatively large. The Data Matrix and RSS have the advantage of requiring little space but need more sophisticated and thus more expensive equipment to be read.

Reading bar codes

There are many kinds of bar-code scanners that are useful for different applications; the application determines which group of devices can be used. For instance, wireless scanners can be needed in healthcare use for patient identification at the bedside. Infrared and radio frequency are used for this purpose, but can only be used in a restricted area. The type of bar code also determines the kind of scanner that is necessary. A two-dimensional bar-code scanner can be used for both linear and two-dimensional bar codes, whereas a linear bar-code scanner can not. A Data Matrix bar code needs an omni-directional scanner. Apart from this, each different set of symbols, such as EAN 128 or EAN 39, is available in different fonts [13]. If a bar-code scanning device is able to read EAN 39, it is not automatically able to read all different fonts and font-heights of this bar code.

Some of the properties of bar-code scanners are worth mentioning. The internal error reduction of a scanner depends on the times per second a bar code is read by the device and on the symbols of the bar code itself. Data matrix symbols, for example, have several internal error corrections. Mathematical formulae are used to reconstruct or replace damaged or missing symbol characters to enable the reading of symbol data [14].

Omni-directional reading means the bar code is scanned in different directions, following a specific pattern. A scanner able to read in all directions can be held upside down and is still able to read the bar code correctly.

Scanners can be divided into four groups based on their light source: LED-scanners, laser-scanners, imager scanners and two-dimensional-imaging scanners. LED-scanners are also referred to as CCD-scanners. Often, internal mirrors are used to correct for reflections and other image-disturbing factors. Laser scanners are capable of long maximum scanning distances. The properties of the light source determine the minimum distance between two adjacent bars as well as the minimum and maximum reading distance. This interval, between the minimum and maximum reading distance, is also referred to as depth of field [15].

Bar-code scanning devices always have built-in software for reading symbols. Simple devices can be compared with a keyboard; while reading the symbols, the characters are presented to the computer, like tapping the keys of a keyboard. The built-in software allows adjustment of the header and footer of the bar code. Simple commands, like "enter", can be programmed into the scanner, so that after reading the bar code the computer jumps to the next insertion field.

All scanner software has the same foundation. Small adjustments of the scanner's software allow the scanning device to communicate with hospital information systems and pharmacy software. Sometimes, this hospital software also needs some adjustment. Data collector software is more complex, the scanner is able to collect data which are transferred to another software program. Data collectors are commonly used in hospitals for ward stock supply.

From a technical point of view, the brand and type of the scanning device is not important. The ideal device for a certain application depends on the kind of bar code, the printer used and the material on which the bar code is printed.

In health care, simple cordless scanners can be used for bedside patient and drug identification. Although two-dimensional, omni-directional bar-code scanners are about 30% more expensive than linear scanning devices, they seem to be the best solution.

Creating and printing bar codes

Different software is available to create bar codes. Even a word processing programme can be used to create linear bar codes, if a symbol is available as true type font. Bar-code software is necessary for creating two-dimensional symbols. This software can create bar codes with different symbols in different fonts and font-heights.

For hospital use, it is necessary to extract data from a hospital information system into the bar-code software. An open database connection can be used to extract data from nearly any database. A bar-coded wristband is easily printed for every hospital patient.

Currently, nearly all available printers are capable of printing linear and two-dimensional barcodes. Sometimes it is necessary to download the bar-code font into the printer before it is able to print the chosen symbol.

Threats and challenges

In logistics, bar-coding has already proven benefits by assuring a greater accuracy during the purchase check on delivery, filling robotics and dispensing cabinets or picking medicines. It helps to: keep the pharmacy database consistent by checking purchased items, reduce errors in the delivery and the inventory recording process. A bar-coded expiry date can prevent distribution of expired medicine and when lot numbers are bar-coded, medicines can be better tracked and traced, which is useful for recall processes. Finally, bar codes are useful on raw materials in order to check the manufacturing, intravenous admixture preparation, repackaging and re-labelling processes.

Bar-coding has the potential to improve the five Rs [16] (right patient, right medication, right dose, right route and right time) when linked to an electronic medication administration record (eMAR). To reach this goal, not only bar-code identification of the medicine is obligatory, but also identification of the patient by means of a bar-coded wrist band and the carer by means of an identification badge or personal code. To prevent medicine being given to the wrong patient, it is important to scan the carer first, then the patient and finally the medicine.

Even if there is no eMAR, bar-coding can still be of value in situations such as an emergency room or post-anaesthetic room; alerts can be generated if the patient can not tolerate certain medicines because of his allergies or other clinical problems. With or without an eMAR, bar-coding can ensure a fast and accurate charting of the given medicine and is able to show pop-up administration guidelines. Another application could be the identification of intravenous admixtures to be recognised by smart intravenous pumps. Last but not least, BPOC is fully dependant on a proper functioning of eMARs and pharmacy information systems although nurses can bypass the system by administering the medication without scanning.

The American Society of Health-System Pharmacists Research and Education Foundation supported the introduction of bar-coding by producing a pharmacist's toolkit to implement a bar-coded medication safety programme in 2004 [17]. In this reference, an overview of challenges to be overcome can be found, which goes beyond the scope of this article.

Having a bar code on every unit dose is the biggest threat and challenge to the broad implementation of BPOC in hospital pharmacy. It is preferable, for quality and efficiency, that bar-coding is done by the manufacturers on every unit dose. In The Netherlands, only half the medicines are bar-coded by the manufacturer on the unit dose. The rest must be done by the hospital pharmacy itself or by dedicated repackaging companies. This might be a reason to choose an expensive central automated dispensing machine, which will be discussed elsewhere in this EJHP Special Edition. However, even when all manufacturers deliver a bar code on their products, there will still be some problems to solve. The most important are multi-dose preparations such as eye-drops, oral solutions, dermatological products and vials, and drugs used in clinical trials.

Recommendations

The manufacturers in Europe must be motivated to deliver unit-dose containers having a bar code with at least the GTIN as specified by GS1 Healthcare, not only for tablets and capsules but also for other unit doses such as ampoules, infusion bags etc. At a later stage, lot number and expiry date can follow. Of course the label must show generic name, brand name, strength, lot number and expiry date.

Parenteral drugs should be labelled with a flag label or peal-off label with the same content. The flag label with bar code can subsequently be transferred to the infusion bag or syringe in order to make bedside scanning possible.

To achieve the goal of better medication safety and efficiency, hospitals or purchasing alliances of hospitals should make bar-coded unit-dosing part of their purchasing specifications.

A general statement and pressure by all European hospital pharmacists, united in the European Association of Hospital Pharmacists, would be the most effective.

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Managing the pharmaceutical supply chain of the Erasmus Medical Centre

Pieter Knoester, PharmD, PhD; Sjaak Kraaij, CPIM; Inger Snijders, MSc

"BETTER, FASTER, CHEAPER" ARE THE THREE WORDS THAT SUMMARISE THE WAYS IN WHICH LOGISTICS MANAGEMENT CAN PROVIDE VALUE FOR CUSTOMERS. THE AUTHORS EXPLAIN WHAT IT MEANS WHEN APPLIED TO THE PHARMACEUTICAL SUPPLY CHAIN.

There is a growing demand from the hospital environment for the hospital pharmacy to provide ever-higher levels of service, quality and cost-awareness. These pressures have produced the need for the pharmacy organisation to be responsive. A responsive organisation puts the customer at the centre of business, and it designs all its systems and procedures with the prime objective of providing value for customers [1]. Recently, we have started a project regarding a redesign of the pharmaceutical supply chain of the Erasmus Medical Centre, Rotterdam, The Netherlands, whose objective is to gain additional customer value.

The pharmaceutical supply chain

The hospital pharmacy of the Erasmus MC employs 100 full-time equivalents of personnel and its annual budget for drugs in 2005 reached approximately €21 million (not including coagulation factor products). The pharmacy department is responsible for all drug supplies to a total of 90 hospital wards and 60 outpatient clinics situated in four different hospitals and a rehabilitation centre. The logistic department of the pharmacy handles, on average, 300,000 orders from the medical wards and outpatient clinics per year, and 98% of these orders are delivered from the pharmacy's stock (the pharmacy's stock value is on average €1.6 million ((not including coagulation factor products). The lion's share of the pharmacy's stock replenishments (72%) is done through a preferred pharmaceutical wholesaler (Interpharm Den Bosch, The Netherlands) either the same day of request or overnight. The current supply chain is illustrated in 1a of Figure 1.

Figure 1: The pharmaceutical supply chain of the Erasmus MC

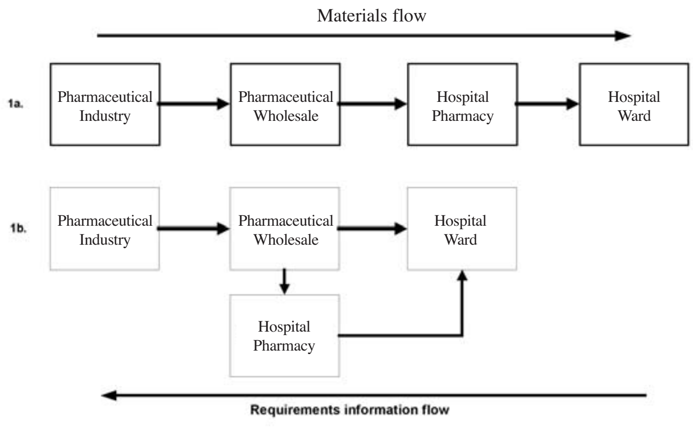

Figure 2: Relative cost reduction of the new supply chain

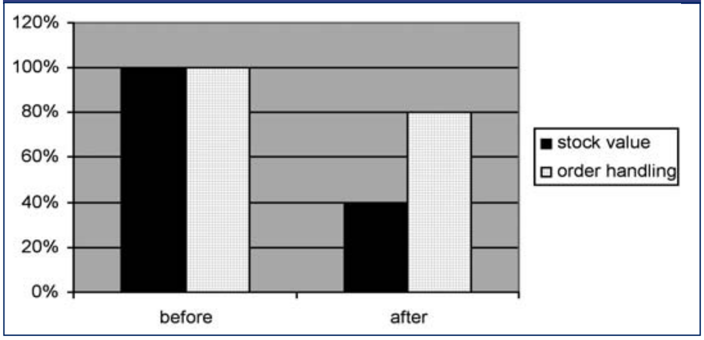

Table 1: Customer satisfaction

Item	Before	After
Quality of stock replenishment		
• availability	7.7 (0.8)	7.8 (0.5)
• timing of delivery	6.4 (1.4)	7.1 (1.0)
• order information	7.4 (0.8)	8.1 (0.6)
Complaint management	7.4 (0.8)	8.3 (0.7)
Overall impression	7.6 (0.8)	8.0 (0.4)

In the aforementioned project, the supply chain is changed (1b of Figure 1) in a way that the stock replenishment of the hospital ward is carried out mainly by the pharmaceutical wholesaler.

The replenishment order for a hospital ward is generated by bar-code scanning. The order is divided by a software tool within the pharmacy's enterprise resource planning system into a part that can be delivered directly by the pharmaceutical wholesaler and a part that will be delivered from pharmacy stores. The pharmaceutical wholesaler picks per hospital ward the drugs needed; on average, 65% of total replenishment is covered in this way. Subsequently, the orders are shipped to the hospital pharmacy of the Erasmus MC. The orders are then transported to the wards by means of internal transport.

The hospital pharmacy delivers the remaining pharmaceutical goods from its own stock. These are mainly drugs with specific restrictions (e.g. controlled drugs), or drugs that are not available from the wholesaler (e.g. drugs manufactured by the hospital pharmacy, large volume intravenous fluids). From May 2005 onwards, this new supply chain design was introduced for a total of 17 medical wards, including two intensive care units.

Better, Faster, Cheaper

The impact of the new supply chain design on the aspects of service level performance, customer satisfaction and integral costs has been evaluated using a before-and-after approach.

The service level performance (defined as the percentage of correctly delivered drugs) was measured in a two-month period before, and at least a three-month period after, the start of the project.

The fulfilment rate before the start of the project was 96.2%, a further 97.4% of orders (n=9,041) were shipped error-free to the customer. After implementation of the new supply chain, the fulfilment rate increased to 97% and 99.4% of the orders (n=14,108) was shipped error-free.

Customer satisfaction, before and after implementation of the project, was evaluated with a questionnaire among 53 nurses. A total of 34 nurses responded (64%); the results are presented in Table 1. Overall, customer satisfaction increased after implementation of the new logistic supply chain.

The impact of the new supply chain on costs is illustrated in Figure 2. The new supply chain will decrease the costs of the pharmacy stock by 60%; costs for handling are reduced by 20%. These savings will partly be offset because of higher costs demanded by the pharmaceutical wholesaler. Our cost model assumes that a full implementation of the new supply chain in the Erasmus MC will at least be cost-neutral, but probably will result in a modest cost saving for the hospital.

Conclusion

We have reviewed the existing order processing system in order to eliminate the 'non-value-added' activities from the perspective of a hospital pharmacy, in this case the delivery of commercially available drugs from the pharmacy stock for the medical ward. The proposed changes in the pharmaceutical supply chain imply a shift from a functional focus to a process focus. The hospital pharmacy remains in the driving seat regarding the logistics. The handling, however, is for a large part delegated to the wholesaler. The first results show that the new approach (i.e. replenishment of drugs from the pharmaceutical wholesaler to the wards) improved the consistency and reliability of the delivered service against the same or possibly lower total costs.

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CAN A CLOSED LOOP SYSTEM ADD VALUE ABOVE AND BEYOND COMPUTERISED PHYSICIAN ORDER ENTRY?

Robert Janknegt, PharmD, PhD; Ann Jacklin, MRPharmS, CSHM; Professor Irene Krämer, PhD

IS UNIT DOSING WITH BAR CODES THE ONLY WAY FORWARD FOR DRUG DISTRIBUTION? THE AUTHORS OF THIS ARTICLE ARGUE THAT THERE IS AN ALTERNATIVE WITH MANY ADVANTAGES.

One of the most important tools in reducing medication errors is, potentially, bar-coding. This is adequately discussed elsewhere in this special EJHP supplement. Suffice to say that in order for bar-coding to be effective, the drugs have to be labelled with a bar code in such a way as to make the bar code available at the time of administration. This has led some authors to believe that the only way to achieve this is via bar-coded unit dose preparation of products. We will describe here how a different system may be of help, without the necessity of bar-coded unit dose packages. Readers may wish to compare this with an ASHP technical assistance bulletin on single unit and unit dose packages of drugs 1985 [1].

Novel systems, such as the ServeRx system from MDG Medical [2] allow the hospital to use conventional hospital containers and also the same packaging as in primary care. The latter may be convenient for the patient as he or she recognises the drug which is used at home (although the relevance of this should not be overestimated as only a few inpatients will actually see the packaging in which their hospital medicines are contained). Recognition of their drugs by patients may potentially also reduce errors during admission to or discharge from hospital.This system is described in this article.

The MDG system

The system is fully integrated and consists of:

- computerised physician order entry (CPOE) software
- nurse workstation
- automated cabinet
- a drug trolley named by MDG as the Smart Cart

These are described in detail below.

CPOE software

The CPOE software runs on a lightweight wireless hand-held device or on a standard desktop computer, using a user-friendly interface and requiring minimal keystrokes. CPOE reduces human errors because of handwriting legibility problems and incorrect transcription, and also reduces the potential for confusion between medicines. If the CPOE software is connected with the hospital's patient information system, physicians have instant access to patient demographic data, graphical displays of the patient's vital signs, weight, height, diagnosis, current medicines and allergies along with medication administration history. The advantages of CPOE have been described extensively elsewhere in this supplement.

Although the ServeRx software is user-friendly and easy to use, the present software is inadequate to be used effectively without active coupling with the pharmacy information system (PIS) or the electronic medical record (EMR). The major shortcomings of the present ServeRx software are a lack of checks on drug interactions, potential contra-indications and over- or under-dosage. Either ServeRx will need to develop this functionality or the CPOE of the PIS or a more advanced CPOE will have to be used, which requires an adequate coupling of ServeRx and the PIS. Hospitals which already have established CPOE may wish to look at sustaining their own CPOE linked to other hospital systems and link this to the medicines-specific aspect of ServeRx as described below.

Nurse workstation

Using the workstation, nurses review medication administration information for their designated patients and adjust configurable time schedules. The ServeRx system helps organise all medicine-related nursing tasks and alerts nursing personnel when tasks are due.

Nurses, pharmacists, physicians, and other clinical staff use the workstation to manage the everyday tasks of the MDG system. The software gives users control over their personal workflow and enables flexibility in how processes are handled including task planning, charting, event reporting, electronic documentation, inventory management, and alerts. This is also true for pharmacist order approval.

Stock medication cabinet

The ServeRx computerised medication cabinet is designed for placement near the patient care area, and is customised with medicine-specific and patient-specific drawers to meet the precise needs of each facility. The total number of drawers may be as high as 500. It is also possible to store refrigerated drugs or controlled substances in these drawers.

Users of the system have to identify themselves by smart cards or passwords. When users have been identified, the (re)stocking of the cabinet can be performed. This can be done by a pharmacy technician or a nurse, or by the wholesaler, depending on the decisions of the hospital in question.

The drawers can only be opened after the correct reading of the bar code of the drug which has to be stored in that drawer. This means that a bar code on multidose packaging is obligatory for optimal use of the system. This is usually the case for most drugs. It is not necessary to have a bar code on a single unit level. Once the bar code has been scanned successfully, one specific drawer will open and the drug must be stored in that drawer. The software calculates the new stock automatically.

The cabinet assists the nursing staff in preparing and administering all the medicines for a particular patient and in managing all medicine-related tasks, such as "stat" drugs (to be given immediately), "when required", over-the-counter, replacement dose, first dose, and, last but not least, regular medicines. All transactions are documented electronically, and high-security access controls ensure that only authorised personnel use the system.

The mobile Smart Cart

The computerised medication cabinet's integrated touch screen displays the medicine orders for each patient including dosage, time and route, to allow nursing verification of the orders. The cabinet opens the dedicated medicine drawers one at a time to minimise the possibility of human error in selection of medicines, while the Smart Cart automatically opens a single patient drawer. This drawer can be for patient A during one round and for patient B during the next round, but is always specific for one patient. The name of the patient in question appears on the display of the drawer. The nurse retrieves the drugs from the cabinet and places them in the patient-specific Smart Cart drawer. The attached bar-code scanner can be used to verify the selected medicines, but this is not necessary, as the drug has already been identified when it was put into the drawer of the workstation. The right type of medicine is ensured by the system, but the number of doses, e.g. two tablets of the same drug, is not verified. Smart Cart preparation can be done during off-peak time. Both pharmacy technicians and nurses can take care of filling the Smart Cart. Only one drawer can be accessed at a time, and the Smart Cart electronically labels each drawer with the patient name using an LCD display. The Smart Cart includes as many as 20 patient-specific drawers and a general drawer for large items such as intravenous (IV) infusions, bulk bottles, and supplies. For IV admixtures, a label is printed with the patient's name, and the name and dosage of the drug. This label is to be put on the prepared infusion solution.

The nurse takes the Smart Cart to the point of care and scans the patient's wristband. The Smart Cart displays the patient's demographic data and medicine orders, and the Smart Cart automatically opens the correct patient-specific drawer. Bar-code scanning of each drug can ensure the accuracy of the drug delivery; however, this is only possible if bar-coded single unit dosage forms are available or the labels of the infusion solutions bear bar codes in order to verify and document the administration by scanning the bar code at bedside. However, as stated before, bar-code scanning is not absolutely necessary and will be labour-intensive for oral medicines. Medicine distribution or administration and the timing are documented electronically. On completion of the drug round, the nurse re-docks the Smart Cart at the medication cabinet.

The medication administration data is then transmitted throughout the ServeRx system, allowing instant access to updated medical information. The empty Smart Cart is then ready for the next medication administration round.

The MDG system has been tested in two European hospitals: Hammersmith Hospital in London, UK and University Hospital in Mainz, Germany.

The main results of the test in London will be published in due course. Preliminary data suggest many advantages and a few disadvantages, some of which are described in the conclusion below.

Conclusion

A centralised unit dose system is not flexible enough in a university hospital where distances are long, changes in medication are more the rule than the exception, and most of the drugs are administered parenterally. The majority of errors happen during prescription and

Figure 1: Overview of the MDG ServeRx system

administration. From an economic point of view these two medication process steps are to be improved.

The ServeRx system looks like an interesting product in that it not only incorporates CPOE but 'closes' the loop with regard to correct drug and patient via novel use of new technology and bar codes. A more sophisticated CPOE will have to be implemented in the (near) future to enforce standardised prescriptions, reduce prescription errors, allow real time therapy monitoring and allow calculation of the medication costs for the individual patient.

There are a few disadvantages to the system: patient-oriented nursing is difficult to support by the ServeRx system. In this approach, one nurse takes care of particular patients for all their needs. Different nurses can not work in parallel using the system. They have to coordinate their work flow at the cabinet and also with the Smart Cart.

The Smart Cart can not enter rooms where patients are isolated or rooms where patients with MRSA and other infectious diseases are treated.

We would urge people who have not yet started to pursue unit dose dispensing to look carefully at their approach — many centres in the US are beginning to reconsider whether unit dosing is the only way to go. Unit dose is resource intensive and medication error rates from the US and UK have been shown to be similar. Unit dosing is a tool to improve pharmaceutical care and not a goal. This suggests that while unit dosing is one way to go, it is not the only way. The ServeRx system may be a valuable alternative. We have started a European cooperation (Germany, The Netherlands and UK) to optimise the ServeRx system for ensuring a safer medication process in the European hospital setting.

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Bedside assortment picking

Krijn Dekens, PharmD; Hans Ros, PharmD; Saskia Coenradie, PharmD; Elsbeth Wesselink, PharmD

BEFORE DRUGS CAN BE ADMINISTERED TO THE PATIENT, INFORMATION HAS TO BE CHECKED AGAINST THE PRODUCT. WITH THIS IN MIND, THE CONCEPT OF BEDSIDE ASSORTMENT PICKING SEEMS AN ATTRACTIVE APPROACH TOWARDS IMPROVING THE SAFETY, EFFICIENCY AND COST-EFFECTIVENESS OF THE MEDICINE-USE PROCESS.

Traditionally, the medicine-use process in hospitals has been described as four consecutive processes: prescribing, transcribing, dispensing and administering of drugs. The processes separate into two parts: one being the transfer of information, from prescription to the administration record, the other being the transfer of drugs from the pharmacy to the point of care. Most medication errors seem to appear with prescribing and administering [1].

The concept of bedside assortment picking (BAP) is based on two main components. The first is an electronic medication administration record (eMAR) which is available wirelessly at the bedside, e.g. by means of a laptop on the drug trolley. Preferably, this eMAR is part of the hospital pharmacy information system and automatically linked to a computerised physician order entry system (CPOE). In this way, the right information is available at the bedside at the time of administration without transcription, even if there have been recent changes.

The second component of BAP is that it uses a dedicated drug trolley or cart (BAP-cart) containing a unit-specific stock of bar-coded, unit-dose medicines.

Before administration, the drugs are scanned and checked against the information on the eMAR. Afterwards the patient is identified through his bar-coded or radio frequency identification (RFID) wristband and the drugs are administered. If the wrong patient is identified, further actions are denied until the right patient is identified or the medicine is replaced in the trolley. A positive identification of the patient at the time of administration leads to greater patient safety than identification of the patient via a computer screen when picking the medicine, e.g. from an automated dispensing cabinet.

Advantages of BAP

BAP has a number of advantages, some of which are closely related to the fact that CPOE, wireless eMARs and bar-code verification are used. The advantages should reduce medication errors and enhance patient safety [2–4]. Without the use of paperwork, all sorts of dosing information are available throughout the system. For example, which drug (and, when appropriate, which lot-number) was administered, at what time by which nurse, and which doctor prescribed it.

The specific advantage of having ward stock available at the bedside is that there is no need to prepare unit-dose carts daily, either manually or by a centralised pharmacy robot. This greatly reduces the workload of filling and checking, eliminates a source of errors and reduces the amount of returned drugs. Even in the case of first dose or stat medicine orders, the required drugs are already available at the bedside in most cases, making the system flexible to urgent needs and medication changes.

Patient safety vs security

With BAP as described above, many guarantees for patient safety are built into the system. It is important to make a distinction between measures to prevent medication errors and measures to reduce opportunities for illegal action.

With BAP, all administrations are registered, making it possible to detect discrepancies between the number of drugs administered and the number of drugs supplied. Thus, potential security leaks can be detected and solved early on. In order to register all non-repeat medicine, the software should support the registration of these medicines in a simple manner.

As well as patient safety and security, other reasons to choose a certain drug distribution system are the ease of inventory maintenance, and efficient and timely resupply of medicines. These are discussed below.

Logistical considerations

There are several ways of inventory maintenance on the BAP-cart. Pharmacy technicians can order supplies on a regular basis, but as all administered medicines are recorded, it is also possible to create refill orders automatically. The reorder level can be set automatically to optimise the process and reduce inventory costs. Early refills would have to be motivated by a doctor or head nurse (or, in some European countries, e.g. UK, by pharmacists who are qualified to prescribe) and reviewed by a pharmacist.

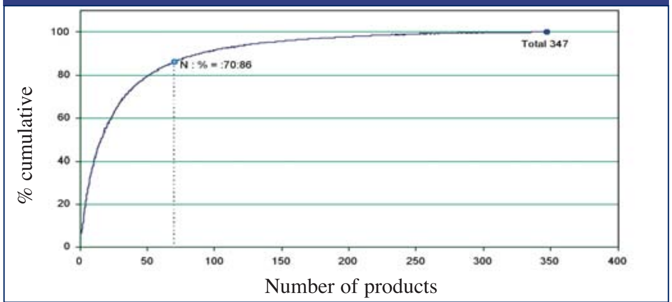
Depending on the drug trolley used, another way of inventory maintenance is the exchange of cassettes that contain the unit specific stock. The cassettes can be replenished in the pharmacy for the next exchange. The amount needed for replenishment can be compared to the amount administered and discrepancies can be reported and discussed.

Because there are far fewer daily patient-specific fills, the amount of returned medicines and the workload are greatly reduced.

Not all required medicines can be placed in the unit specific BAP-cart, because of lack of space or the need for special precautions (e.g. refrigeration, controlled substance). To decide which products should be in the inventory, ABC-analyses can be performed on the basis of volume or costs of the drugs used on the ward concerned. [ABC analysis (also referred to as the 80/20 rule and as Pareto analysis) is a method of classifying items, events, or activities according to their relative importance. It is frequently used in inventory management where it is used to classify stock items into groups based on the total annual expenditure for, or total stock-holding cost of, each item. Organisations can concentrate more detailed attention on the high value/important items. Pareto analysis is used to arrive at this prioritisation.]

As an example, a graph is shown in Figure 1, representing the cumulative amount of unit-doses over a period of six months vs the number of products used on a 30-bed cardiology ward in the Martini Ziekenhuis, Groningen, The Netherlands. The vertical line shows that in this case 86% of the doses can be picked from an inventory comprising 70 (about 20% of a total 347) of the most used products.

Figure 1: Cumulative amount of unit doses vs number of products used



The graph also shows that as much as 40% of the doses could be picked from the bedside assortment if only 10 articles were placed in the inventory of the drug trolley. Even in systems with centralised dispensing robots, it is worth considering the use of a BAP for a few selected drugs.

A similar situation was observed on a neurology ward in the Gelre hospital, Apeldoorn, The Netherlands. A total of 84 medicines accounted for 80% of the doses that needed to be picked. This is a little less than 20% of all used medicines during one year (488 medicines).

When a patient's medicine is not in the inventory of the BAP-cart, it could be stored in patient-specific drawers on the trolley, or in patient-specific, bedside medicine cupboards. The latter solution saves valuable space in the BAP-cart.

Other considerations/pitfalls

There are a number of other considerations to be taken into account when BAP is used:

- It is important that every single dosage form is provided with a usable bar code. At the moment, in The Netherlands, a large number of drugs do not have usable bar codes. For these drugs, repackaging is the only solution to make BAP become truly effective.
- When working with BAP, the packages and blisters of drugs should be easy manageable. Removing blisters from boxes and/or tearing blisters can be troublesome at the time of administration.
- In some systems, the nurse can collect the drugs for all patients before administration. In this way, medication errors can occur again when medicines become mixed up. This is preventable when, after the medicines for a patient are picked and scanned, all further actions are denied until the right patient is also scanned.

Drug trolleys

A drug trolley for BAP must have several characteristics. First, it has to be provided with a wireless bar-code scanner and a wireless laptop. To make sure these instruments can be used for several hours at a time, they must be equipped with a supplemental external power supply that is built into the trolley. While it may seem attractive to store many different products in the trolley it must be easy to manoeuvre, otherwise it will not be used at the bedside but merely as a unit-based cabinet.

Ergonomic design is important: repeated bending or kneeling by nurses should be avoided.

Sophisticated trolleys are equipped with access-controlled drawers, bin guide lights and real-time access monitoring, providing added security and ease of use. However, these advantages come at a high price and need additional software interfacing which can often be cumbersome.

First experiences with the BAP-cart

In Apeldoorn, The Netherlands, the BAP-cart has been in use for almost half a year. In a questionnaire among 26 nurses on a neurology ward in Gelre Ziekenhuizen, their satisfaction with the BAP-cart has been assessed.

According to the nurses, the main step forward after using the BAP-cart for three months, is the use of wireless eMARs. Also, the extended number of medicines stocked in the BAP-cart is reported as an important improvement. The users experienced the control of the BAP-cart (manoeuvring, kneeling and bending) as a main disadvantage. Nevertheless, the handling of the scanner and the wireless laptop is no problem; more than 90% of the responders used the software confidently.

The BAP-cart should be equipped with a sufficient amount of medication, but not to the extent that it is too large to handle.

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Using automated dispensing machines to improve medication safety

Hadewig B B Colen, PharmD, PhD; Mark Neuenschwander; Cees Neef, PharmD, PhD; Professor Koos J Krabbendam, PhD

THE FINAL PAPER IN THIS EJHP SPECIAL EDITION DISCUSSES THE LOCATION IN THE LOGISTIC SYSTEM WHERE AUTOMATED DISPENSING MACHINES MAY BE USED TO REDUCE MEDICATION ERRORS. THE AUTHORS ALSO SUMMARISE THE RECENT STUDIES AND EVALUATE THE AUTOMATED DISPENSING MACHINES NOW AVAILABLE.

Generally speaking, logistic systems involve a medication flow, consisting of an information flow and a material flow. Sometimes these are coupled in the logistic process and at other times they are decoupled because information is received via other channels. Information is generated from various sources: the physician, pharmacist or the pharmaceutical industry. This information will concern the patient and/or the drug.

Medication errors are often a result of a badly organised distribution process. In our error studies we found that, although a patient expects the right drug at the right time, 20% of medicines are administered at another time than prescribed, simply because a drug is not available in the ward or at the patient's bedside. There may be delays of as much as three days before a drug is on the ward [1].

The following elements have been studied to work out an improvement in medication safety: material flow, supply modes, storing conditions and management, medication-order decoupling points and automated dispensing machines (ADMs). This paper discusses the location in the logistic system where ADMs may be used to reduce medication errors.

ADMs to support logistic systems

ADMs in hospitals may include both centralised and decentralised automated devices and may be used for unit-dose or bulk medicines. Besides, combinations of centralised and decentralised automated devices can support a hybrid logistic system. A range of qualities may be defined for the ADMs. If the unit-dose medicine system is used, each single drug dose may be identified, including its expiry date and batch number.

Centralised ADMs for unit-dose dispensing

Centralised machines are used for dispensing routine orders for patients. For acute care, the machines are used to dispense a 24-hour supply; for long-term care, they might dispense orders in three, seven or more strip packages. Some centralised machines repackage bulk medicines and some use over-packaged, manufacturer-wrapped units. Some centralised machines produce patient-specific packaging, which includes patient name, drug strength, date and dispensing time. Medicines arrive at the bedside with bar codes that can be scanned.

Centralised ADMs are used increasingly to assist stocking automated cabinets (decentralised machines). Interestingly, most hospitals with centralised machines employ decentralised automated cabinets for "when required" (PRN) drugs, controlled drugs and first doses.

ADMs may stand alone or be integrated within decentralised machines to accomplish medicine distribution in a hospital or in a group of hospitals and nursing homes. There are several centralised ADMs for central unit-dose medication preparation on the market. An inventory was made of information available from our own experience as well as from distributors and information presented at the EAHP and ASHP Exhibitions 2002—2005, e.g. by Neuenschwander [2]:

- For oral unit-dose solids: FastPak (by Automed), Pacmed (by M.E.D.S and McKesson), Safety Pak (by Omnicell) and Autopak (by Talyst)
- For oral unit-dose solids, liquids and ampoules: AutoFill (by Automed); however, AutoFill has not yet been installed in Dutch hospitals
- For all kinds of unit-dose products: Athena system (by Sinteco-robotics), Drugnest /Pillpicker (by Swisslog) and the Robot-Rx (by McKesson)

The individual characteristics of each machine are beyond the scope of this article.

The pros of a central machine:

- Automated unit dose
- Ability to scan the packaging of all available drugs on the market that have bar codes
- Automated unit-dose and bar-code-controlled drug dispensing

The cons of a central machine:

- No central stock on the ward
- No automated solutions for the supply of inflammable drugs, blood derivates and cytostatics
- Time delay

Centralised ADMs for bulk and unit-dose medicines

There are a few central machines for bulk and unit-dose medicines on the market, such as the carousel, which is an automated warehouse for drugs in their original packaging. In the US, carousels are offered by Cardinal Health as Pyxis Carousel, by Omnicell as Pharmacy Central, by McKesson as MedCarousel, by Automed as FastFind and by Talyst as AutoCarousel.

These automated systems are designed to maximise workplace productivity and reduce storage for medicines in the central hospital pharmacy. There are also European companies that offer similar systems, such as Boxpicker from Swisslog and the ROWA machine.

These machines are used in countries such as the UK that do not use unit-dose systems. They are certainly valuable in combination with other ADMs but in relation to the scope of this article (unit-dose dispensing) they will not be discussed in more detail here.

Table 1: Decentralised ADMs: AcuDose-Rx, MedSelect, MedStation, OmniRx, ServeRx, Medihive, Hydra

Product groups	All regular formulary drugs except special drugs and individual preparations.
Product protection	All products have the original manufacturer's packaging.
Product information	In accordance with manufacturer conditions.
Package volume/ weight efficiency	Some manufactured volumes are not suitable for drug distribution.
Handling ability of packaging	Some packaging is difficult to handle.
Supply mode support	Order-picking, unit supply.
Hardware	All seven systems have drug-specific drawer configurations. A few have patient specific drawer configurability options. Most offer finger print technology as access to stock. All offer other options, e.g. enter name and password or swipe card and enter password. The system is linked to the patients' information system (PIS) and the hospital information system (HIS). All drug activities are registered. Thus, consumption per patient is registered on the basis of which stocking alert is automatically given (pull principle). The automatic stocking, drug-consumption registration, the costs per patient as well as the operator's identification have been safeguarded. The system makes use of patient profiles supplied by PIS.
Software interfaces	Interfaces are written in compliance with specifications that support protocols produced by the HL7 organisation for the development of standards. (Health level seven is an organisation credited by the American National Standards Institute to develop standards in health care.) The server processes data received from PIS and/ or HIS.
Stocking/restocking	Consumption per patient is registered on the basis of which a stocking alert is automatically given.
Flexibility	Suitable for all kinds of products, drugs and medical devices.
Validation	Proven technology except Hydra and Medihive.
Costs	Time is saved by avoiding manual activities (e.g. with controlled drugs). Automated stock management can impact costs.
Strengths	Automated stock management. Patient profiles, colour touch screen, wide variety of single-item, matrix, supply cabinets dispensing devices. Excellent narcotic control. Simple technology with off-the-shelf parts. Single item dispensing components. Hydra has spirals for storage of single item storage dispensing components. Medihive uses pins to store single items dispensing components. MDG ward-based workstation manages the medicine administration process as well as controlling the ward inventory.
Weaknesses	Matrix drawers increase the chance of errors when stocking, dispensing and returning medicines. Stocking at stations stand to be labour and time-inefficient.

Decentralised ADMs for unit-dose medicines

There are several decentralised ADMs for unit-dose drugs available: AcuDose-Rx by McKesson Automation Group, MedSelect by Medselect System, MedStation by Pyxis Corporation, OmniRx by Omnicell.com, Medihive by Swisslog and Hydra by Sinteco. Again, the individual characteristics of each machine are beyond the scope of this article. Table 1 shows a summary of their collective characteristics.

The pros of a decentralised system:

- Safe access for authorised-only users
- Automated stock management
- Automated dispensing for controlled substances and ward stock medicines
- Nursing time saved
- All data is logged

The cons of a decentralised system:

- Possibility to pick several items together
- Time lapse between picking and registration of administration
- Possibility for override

Combination of centralised and decentralised ADMs for unit-dose dispensing

Combinations of the above centralised and decentralised ADMs are possible to support hybrid logistic systems.

Matching ADMs and supply modes

Various logistic systems are used in healthcare institutes by both human and technological resources to carry out the actual distribution process that must ensure that each physician-ordered and pharmacist-reviewed drug is available to the nurse for administration to the patient in the correct dosage in a timely manner.

We studied the location in the logistic system where ADMs may be used to reduce medication errors. Therefore matches of ADMs with supply modes, material flow and drug characteristics should be made, as shown in a thesis submitted by one of the authors of this article, Colen: *Improving safety and quality of care through optimisation of the drug distribution process in healthcare institutes as well as others* [3].

Various ADM combinations are possible to support the logistic system to improve the quality of care. However, they can not be used for all products.

The matches may be categorised into direct or indirect systems. In a direct system (decentralised stock or stock-on-wheels), most of the process handling, i.e. dispensing, distribution and control, takes place near the patient. In an indirect system (centralised stock), the packaging and dispensing is carried out in the central pharmacy. A hybrid system combines the indirect and direct systems.

A decentralised ADM may be used for a large assortment in small volumes to guarantee availability of drugs at the patient's bedside and their administration on time.

In small healthcare institutes, these decentralised ADMs may be used for when required medicines and first doses in combination with manual drug dispensing in the central pharmacy, satellite or ward. In large healthcare institutes these decentralised ADMs may be used to support decentralised storage of regular drugs, controlled drugs and blood products.

If centralised ADMs, such as robots, are used, drugs will be dispensed automatically so that nurses have time left for other patient care-related activities and dispensing errors will be reduced. In large healthcare institutes these central robots may be combined with decentralised automated cabinets.

Conclusion

The question is if and how can the available ADMs be used in the various logistic systems?

ADMs feature computer-controlled mechanical devices that package and/or dispense, distribute and control medication.

ADMs now available are extremely expensive compared with the equipment pharmacy departments purchased in the past. Most of the machines are complex systems that require major changes in traditional pharmacy, nursing and medical work systems.

In the early days of their availability, healthcare institutes in the US bought new ADMs to capture lost charges. Healthcare reimbursement structure changed and this value all but vanished. Subsequently, institutes bought ADMs assuming that they would save labour, often without evaluating other equally important objectives. As a result, some have been abandoned because of problems with their design, their impact on workflow and general dissatisfaction with them by end-users [4].

ADMs in hospitals may include both centralised and decentralised automated devices and may be used for unit-dose or bulk medicines. In addition, combinations of centralised and decentralised automated devices can support the hybrid logistic system.

The ADM choice depends on the demands made on the care-institute's logistic process and the type of medicines they dispense the most on the basis of the patient categories they treat. A specialist centre, such as an oncology unit, may not be interested in certain parts of the logistic system. In general, we expect that in a healthcare institute of 1,000 beds or more, caring for all patient categories, a hybrid logistic system that incorporates centralised robot technology with decentralised dispensing cabinets will perform best with regard to logistic functionalities.

Implementation of new technology in the drug distribution process necessitates a complete redesign of services and considerable requirements. Therefore, novel technology in this area should have proven benefits on medication safety and completed evaluation of appropriateness before hospital-wide implementation is recommended. If the implementation of design principles is ignored, the risk increases that users (physicians, nurses, pharmacists, pharmacy technicians) will reject the technology that could ultimately improve patient safety.

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