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Reducing the number of dispensing errors by implementing a combination of a CPOE system and a bar-code-assisted dispensing system: the BAP concept

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Abstract

Introduction: Medication errors occur frequently in hospitals. A computerised prescriber order entry (CPOE) system together with bar-code-assisted dispensing can reduce the error rate.
Method: A complete business process redesign was undertaken and evaluated in two steps. Using a direct observer method to detect dispensing errors by nurses, the impact on patient safety of the implementation of a CPOE system (step 1) combined with bar-code-assisted dispensing (step 2, using bedside assortment picking [BAP]) was investigated.
Results and discussion: The implementation of a CPOE system resulted in a reduction in the dispensing error rate of 47% in comparison with the pre-CPOE phase (from 3.1% to 1.7%). BAP resulted in an additional reduction in dispensing errors of 49% (from 1.7% to 0.84%). Overall, a reduction of errors of 73% was obtained.
Conclusion: The BAP concept was able to improve medication safety in the hospital significantly.

Keywords

BAP, business process redesign, CPOE, dispensing errors

Introduction

Medication errors are a major concern for healthcare professionals and medical institutions. In Gelre Ziekenhuizen, physician prescriptions are handwritten and the drug administration rounds are supported by medication administration records (MARs) on paper. This way of organising the process comes with a high risk of dispensing errors. Prescribing errors are an important source of dispensing errors: often, handwritten prescriptions are not complete and can be difficult to read properly. It is well known that a computerised prescriber order entry (CPOE) system combined with electronic registration of administration is crucial for reducing dispensing errors: international literature reports up to 81% error reduction using such a system [1-4].

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In addition, bar-code technology has been recommended as a safe medication practice and can be used to improve the safety of drug administration at the bedside. By identifying a drug by its bar code the chance to pick a wrong drug from a drug trolley should decrease.

The whole process from prescribing to dispensing to administration of medicines is a complex one. With this study, a complete business process redesign was realised in three phases. A business process redesign is considered to be the best way of improving complex processes that have large error rates [5].

In this prospective observational study, the impact on dispensing errors of the implementation of a CPOE system and the subsequent implementation of bar-code-assisted dispensing of drugs is presented. The effects at all steps were investigated.

Method

Study design

A prospective observational study was performed, incorporating a direct observer method to detect dispensing errors by nurses.

Direct observation is an accepted method of detecting errors, which yields more information than looking at patients' drug charts or analysing voluntary reports of errors [6-12]. The method consists of an observer witnessing the administration of medicines to patients by the nurse.

The observer checks the giving of each dose by the nurse with the help of an exact copy of the MAR. Because the observer is present at each phase of the study, the possible effect of his/her presence on the number of dispensing errors is negligible. To avoid introducing a bias to the study, observers do not intervene if an error is observed. If the observer estimates that the patient's safety is compromised, a warning is given to the nurse before the medicine is actually taken by the patient.

In the study described here, during each observation period the scheduled drug administration rounds (8 a.m., noon and 5 p.m.) were observed daily for 21 days; weekends were included. One hour after each round the observer checked to ensure that all medicines had been taken by the patient.

During all phases of the study, doctors, nurses, pharmacists and pharmacy technicians recorded the time they spent on every aspect of the medication process. Simple registration forms were used for this purpose.

The study consisted of the following phases:
Phase 1: pre-CPOE
- The physician wrote a prescription by hand.
- The pharmacy technician transcribed the hand-written orders into the hospital pharmacy information system for generating a MAR for each patient. Every transcribed order was checked by a second pharmacy technician to check for prescribing errors. Each day, the dispensed medicines were transferred from the pharmacy to the ward in a conventional drug trolley. The trolley was filled by a pharmacy technician and again was checked by a second pharmacy technician in order to reduce the risk of errors.
- The nurse gave the medicines to the patient; the nurse signed the MAR after giving the medicines.
- The ward pharmacist took responsibility for medication alerts from the CPOE system.

Phase 2: post-CPOE
- The physician used CPOE to prescribe medication.
- The pharmacy technician checked the electronic orders in the hospital pharmacy. These comprised a check on correct dosage and proper use of the hospital formulary. In addition, computer-generated medication alerts, e.g. incorrect doses, interactions, contraindications, were processed by a hospital pharmacist, which occasionally led to interventions. Interventions were documented in the CPOE system. Each day, the medication was transferred from the pharmacy to the ward in a conventional drug trolley.
- An electronic medication administration record (eMAR) was available for the nurse at the bedside wirelessly, e.g. by means of a laptop on the drug trolley. The nurse signed electronically after administering each drug.

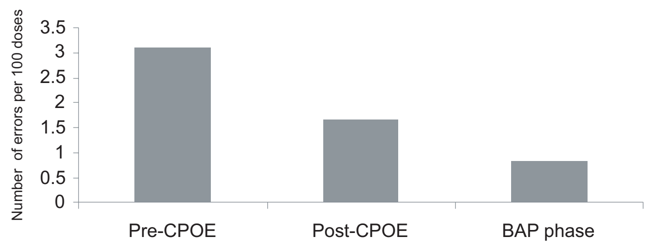
Phase 3: Bedside assortment picking BAP phase (December 2005)
- As in phase 2, the physician used CPOE to prescribe medication.
- As in phase 2, the electronic orders were checked in the hospital pharmacy. A dedicated drug trolley, the BAP cart, was introduced, which carried a large stock of medication. If prescribed medication was not available on the BAP cart, it was to be dispensed and stored on the BAP cart as patient-specific medication for seven days.
- The use of eMARs was extended. The patient was identified by a label with a bar code that was read by a retail/commercial cordless scanning system from Adaptus Imaging Technology (model: IT5620). The label with bar code originated from the hospital information system (Roccare from Pick Roccade). After identifying the patient, the computer presented the medicines for the current round one by one. The bar code of every drug was scanned and checked against the information on the eMAR before administration. The process was completed by scanning the wristband of the patient again when the medicine was given to the patient. When a wrong drug or wrong patient was scanned, a computer signal popped up and the process was stopped until the right patient or drug was identified.

Setting
The study was conducted in a 36-bed neurology ward including an eight-bed acute stroke care unit (where intensive care is given) at the Lukas Ziekenhuis in Apeldoorn, The Netherlands (Gelre Ziekenhuizen). The hospital pharmacy information system used Pharma (TM Software), with an integrated CPOE and a module for electronic medication administration. The CPOE system only supported prescribing; it contained all drugs available in The Netherlands, with a preset of preferred items. The system automatically generated alerts for overdosing, interactions and contraindications. It did not support the choice of a drug following a stated indication.

The BAP concept was developed by Medi-Math Medilux BV and the Gelre Ziekenhuizen hospital pharmacy using Brocacef intramural and TM Software.

Definitions
A medication error is any preventable event that can cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient or consumer [13]. An important subset of medication errors are errors in dispensing. A dispensing error is defined as any discrepancy between the prescriber's

Figure 1: Results



medication order (hand written or electronic) and what was actually dispensed to a patient.

A dose of a medicine, given to a patient, has been defined as an opportunity for an error [11]. Any given dose was determined to be either correct or incorrect. In this study, doses were only included when both the preparation and administration of the medicine was witnessed by the observer. The study included observation of each type of medication preparation.

The total number of possible errors is the sum of all doses ordered and the number of unordered doses given.

Bedside assortment picking

A new type of drug trolley was developed and introduced in phase 3. The new trolley consists of a compartment that contains ward-specific stock and a compartment with patient-specific medicines. The trolley is equipped with a wireless laptop in order to support eMARs. At the patient's bedside, the software system guides the nurse to the right location of a drug in either the stock medication compartment or the patient-specific medication compartment. This means that ward-specific stock medicines, which are on the BAP trolley, only become patient-specific when they are actually given to patients. This led to the term bedside assortment picking (see Figures 2 and 3).

Figure 2: Front view of the BAP cart

Data analysis

Panel 1 lists classification of dispensing errors. The dispensing error rate was calculated as the number of actual errors divided by the total number of possible errors.

Figure 3: The drawer with stock (double bin system)

Time errors (category V) are an indicator of the quality and efficiency of a medication system. Because a drug administration round often lasts for more than 60 minutes, time errors frequently occur. For most drugs used on the neurology ward, time errors have almost no influence on patient safety. Therefore, error rates both with and without time errors were listed. In the analysis, only results that were not category V were assessed; the literature shows this to be common practice.

To compare time investment by nurses, technicians and pharmacists in the different observation periods, the time was related to the number of doses per day. Therefore, the total number of doses from 8 a.m., noon and 5 p.m. was counted.

Statistical analysis

The mean error rate in the three observation periods was compared and tested for significant differences with a X^2-test, if necessary with Yates-correction for small sample amounts.

One-way analysis of variance (ANOVA) was performed to test for significant differences in mean error rate per 100 doses during the 21-day observation period. One-way ANOVA was also used to determine differences in mean time spent by physicians and nurses. The difference in mean time spent in the hospital pharmacy per 100 doses was tested for significant differences by one-way ANOVA.

Results

Statistically, in the post-CPOE phase, a reduction in error rate of 47% was obtained in comparison with the

Panel 1: Classification of dispensing errors [14]	
I	**Unordered drug** A drug is administered without an order from a physician
II	**Extra dose** Every dose after the prescribed number of doses, e.g. after stopping the prescription
III	**Wrong dose** Every dose administered with the wrong strength or wrong amount. For a parenteral preparation a deviation of more than 10% from the correct dose is defined as a wrong dose.
IV	**Omission** In the following situations, a dose not administered is not considered to be wrong: • When a patient refuses a drug • When a dose is not administered because of planned surgery • When a drug could not be dispensed to the ward
V	**Wrong time** A drug has not been administered within 60 minutes from the planned time of administration. A 30-minute window applies to drugs that need to be administered with a meal.
VI	**Wrong route of administration** Medication is administered by a different route to that ordered by the prescription, e.g. IV instead of IM. This category includes: • Doses administered to the wrong location, e.g. in the right eye instead of the left eye • Incompatibilities of parenteral drugs
VII	**Wrong form** Medication is administered in a different formulation than that prescribed, e.g. an uncoated tablet instead of an enteric-coated tablet
VIII	**Wrong administration technique** Medication is administered without complying with instructions, e.g. not preparing a correct infusion. Instructions concerning use with the patient in an upright position also fall into this category.

pre-CPOE phase; the error rate dropped from 3.1% to 1.7%. In this phase, errors in category I, II, IV, VI and VIII showed a statistically significant decline in occurrence (see Table 1).

In the BAP phase, an additional reduction in error rate of 49% was obtained in comparison with the post-CPOE phase; the error rate dropped from 1.7% to 0.84%. Compared with the second phase, errors of category III occured less frequently in the third phase (eight errors compared with 23 errors). The difference in the number of errors in both phases is statistically significant (see Table 2). Overall, a reduction of errors of 73% was obtained for which almost all error categories (I, II, III, IV, VI and VIII) were responsible (see Table 3 and Figure 1).

In absolute numbers, 1.7 errors per day were made in the BAP phase in contrast to 6.4 errors a day in the pre-CPOE phase.

As well as recording medication errors, the time component was also measured. Physicians, nurses and hospital pharmacy employees recorded time spent on the medication process during each phase of the study. In total, the new process was no more time-consuming for each and every professional group than the old process.

Discussion

The results of the study correspond with comparable studies from international literature [1-4]. The main reason for a major reduction in dispensing errors is believed to result from the fact that eMARs are automatically linked to the CPOE. Therefore, the right information is in real time and available online at the bedside during medication rounds, even if changes are carried out just before the round. All kinds of dosing information are made available by the software system, without the use of paperwork. For example, which drug was administered, at what time by which nurse, and which doctor had prescribed it. This system leads to a situation where several sources of errors are eliminated, which enhances patient safety.

In this study, the advantage of bar-code verification was proved by an extra reduction of medication administration errors of 49% on top of the results after introduction of CPOE and eMARs. A reduction of error category III in this phase is statistically significant and is explained by the fact that the computer system automatically brings doses that differ from one unit dose, for example one half or two tablets, to the nurses' attention.

BAP is technologically difficult to effect. A cordless network is needed that is well protected against hackers. The laptops continuously need to have contact with the network, and with contact to the cordless scanners. Technological support from an IT department is an absolute requirement for the smooth running of the system.

The BAP trolley is a large trolley that is heavier than a conventional trolley. It needs specific working conditions, e.g. for the force to get the trolley in motion, or for the force that is needed to go around a corner. Also, requirements are formulated for easy accessibility of the drugs, e.g. without the need to bend over too frequently.

The software programme is the key element for this process redesign. It needs to support all stages of handling medicines from the minute the doctor has introduced a

Table 1: Error rate per category of errors pre-CPOE versus post-CPOE

	Pre-CPOE (n = 4,457)		Post-CPOE (n = 3,814)		Difference	p	RRR*
	Number of errors	%**	Number of errors	%**			
I Unordered drug	13	0.29	5	0.13	-0.16	0.1 < p <0.2	0.56
II Extra dose	9	0.20	1	0.03	0.17	<0.05	0.87
III Wrong dose	21	0.47	23	0.60	+0.13	>0.02	-0.27
IV Dose not administered	57	1.28	23	0.60	-0.68	0.001 < p <0.01	0.53
V Wrong time	181	4.06	159	4.17	+0.11	>0.20	-0.03
VI Wrong route of administration	11	0.25	1	0.03	-0.22	<0.05	0.89
VII Wrong preparation	0	0.00	0	0.00	0	-	0
VIII Wrong administration technique	27	0.61	9	0.24	-0.037	<0.05	0.61
Total	319	7.16	222	5.79	-1.37	0.01< p <0.02	0.19
Total (excluding category V)	**138**	**3.10**	**63**	**1.65**	**-1.45**	**<0.001**	**0.47**

*RRR: relative risk ratio at 95% confidence interval; **Percentage of the total number of observed doses

prescription to the CPOE system (and it is at this time that the information regarding the prescription is immediately available for nursing staff), through to their administration to the patient. Several adjustments were needed before the software programme was equipped for this study. Nevertheless, even after implementation, several new requirements were encountered that needed to be incorporated in the software before introducing the BAP system to other wards.

Table 2: Error rate per category of errors post-CPOE versus BAP phase

	Post-CPOE (n = 3,814)		BAP phase (n = 4,300)		Difference	p	RRR*
	Number of errors	%**	Number of errors	%**			
I Unordered drug	5	0.13	1	0.02	-0.11	<0.07	0.82
II Extra dose	1	0.03	2	0.05	+0.02	<0.64	-0.77
III Wrong dose	23	0.60	8	0.19	-0.41	<0.002	0.69
IV Dose not administered	23	0.60	16	0.37	-0.23	<0.13	0.39
V Wrong time	159	4.17	264	6.14	+1.74	<0.0003	-0.47
VI Wrong route of administration	1	0.03	0	0	-0.03	<0.29	1
VII Wrong preparation	0	0.00	1	0.02	+0.02	<0.35	N/A
VIII Wrong administration technique	9	0.24	8	0.19	-0.05	<0.62	0.22
Total	222	5.79	300	6.98	+1.19	<0.03	-0.20
Total (excluding category V)	**63**	**1.65**	**36**	**0.84**	**-0.81**	**<0.0008**	**0.49**

*RRR: relative risk ratio at 95% confidence interval; **Percentage of the total number of observed doses; N/A: not applicable

New developments were not only necessary for the software, but also for the BAP medication trolley. The study was conducted with a simple demonstration trolley. At the moment, this model is being rebuilt to produce a professional trolley; this will take some time. The new trolley will not only have a more sophisticated external appearance but will be more user-friendly.

The most important threat to patient safety is the lack of availability of bar codes. Not all drugs carry a bar code at the unit-dose level. In the study, 80% of all drugs could be identified using a bar code. That means that 20% were administered without bar-code verification. A subsequent problem was that not all available bar codes could be read easily with the scanner; sometimes the bar code had to be scanned several times before it could be read. Nurses did not always take the time to finish this procedure, leading to a

Table 3: Error rate per category of errors pre-CPOE versus BAP phase

	Pre-CPOE (n = 4,457)		BAP phase (n = 4,300)		Difference	p	RRR*
	Number of errors	%**	Number of errors	%**			
I Unordered drug	13	0.29	1	0.02	-0.27	<0.0016	0.92
II Extra dose	9	0.20	2	0.05	-0.15	<0.04	0.77
III Wrong dose	21	0.47	8	0.19	-0.28	<0.02	0.61
IV Dose not administered	57	1.28	16	0.37	-0.91	<0.0001	0.71
V Wrong time	181	4.06	264	6.14	+1.85	<0.0001	-0.51
VI Wrong route of administration	11	0.25	0	0	-0.25	<0.001	1
VII Wrong preparation	0	0.00	1	0.02	+0.02	<0.309	N/A
VIII Wrong administration technique	27	0.61	8	0.19	-0.42	<0.0018	0.69
Total	319	7.16	300	6.98	-0.18	<0.74	0.03
Total (excluding category V)	**138**	**3.10**	**36**	**0.84**	**-2.26**	**<0.00001**	**0.73**

*RRR: relative risk ratio at 95% confidence interval; **Percentage of the total number of observed doses; N/A: not applicable

situation in which although a bar code was available, the scanner was unable to read it and therefore it was not used in the process.

It is most important to improve the number of products with a good readable bar code on unit doses. Only a combined effort from all hospital pharmacists across Europe will lead to a complete set of drugs with bar codes on products at the dispensing level. Although bar codes are requested especially for the hospital setting, bar-code-assisted dispensing can also lead to improved medication safety for patients in nursing homes, for example.

Study weaknesses

It is well known that the introduction of a CPOE system leads to new errors in prescribing. Choosing the wrong patient or choosing the wrong drug from the formulary are the most common new errors. These errors can form an important threat to patients' safety; moreover, they are difficult to trace. This study was not aimed at finding these new errors.

Because of the major time investment to develop the new BAP concept, the total study period (from pre-CPOE to BAP phase) took almost three years. In the meantime, other circumstances changed on the neurology ward. For example, the number of staff on the ward and the mean length of hospital stay per patient reduced. Consequently, staff workload was higher at the end of the study. On top of that, the composition of the staff changed by natural wastage, so that the study population on the neurology ward was not exactly the same all the time.

Errors made in the transcription process during phase 1 (pre-CPOE) were not observed. Therefore, the medication on the MAR could be dispensed correctly by the nurse, even though the prescriber intended a different drug.

Conclusion

In Gelre Ziekenhuizen, the two phases of introducing the BAP concept showed a 73% reduction in dispensing administration errors. With these results, the BAP concept has demonstrated its ability to improve medication safety significantly in the hospital.

This study leads to several new demands that need to be incorporated in the software and the BAP trolley before the BAP system can be implemented on other wards. Much effort needs to be invested in the availability of bar codes for unit doses.

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