Information technology and medication safety

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Overview of strategies to improve the safety of medication administrations in hospitals

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Stand van zaken: Veilig toedienen van geneesmiddelen in ziekenhuizen

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ABSTRACT

Every day thousands of hospital inpatients receive medication. Medication administration may be erroneous. This chapter is aimed to provide an overview of strategies for the safe administration of medication in hospitals with a focus on Dutch hospitals. Strategies include training, double checking procedures, and technological solutions (such as smart infusion pumps and barcode-controlled drug administration). Most of the intervention studies are small which limits the generalizability of the findings. More work is needed to identify the best solutions.

INTRODUCTION

Patient safety is an important issue in Dutch hospitals. Preventing unintended and avoidable patient harm is a top priority. In 2008, the Safety Management System (Veiligheids Management Systeem, VMS) safety program (www.vmszorg.nl) was launched with the aim to reduce potential patient harm by 50% focusing on ten areas. In four of them, medication was the main topic: safe prescribing, safe preparation, and medication verification upon patient admission to hospital and discharge, and safe administration of medication, particularly high-risk medication.

Medications are administered to thousands of patients daily in Dutch hospitals, mainly by nurses. Often these are ready-to-use drugs, such as tablets, capsules, suppositories, or liquid medications. In some cases, medications have to be prepared before administration, for example for an injection. Nurses ensure that medication is taken correctly and record the administration in the patient record. During all of these steps, medication administration errors can be made. A medication administration error is a deviation in the preparation or administration of a drug from a doctor's prescription, the hospital's intravenous policy, or the manufacturer's instructions [2]. This includes actions necessary to prepare the medication for administration (extemporaneous compounding). Table 1 provides an overview of administration errors and examples. Medication administration errors can cause unintended harm to the patient [2]. There are a few possibilities to detect and prevent an administration error promptly. Unlike prescription errors, where the electronic prescribing system generates warnings, hospital pharmacists monitor medication, and pharmacist's assistants or nurses check the medication when they are prepared, only an attentive patient or a double-check by a second nurse may prevent a medication administration error.

Hospitals in The Netherlands have invested in patient safety and medication safety in recent years based on the VMS program. The Netherlands Institute for Health Services Research (Nederlands Instituut voor onderzoek van de gezondheidszorg, NIVEL) and research institute EMGO+ (Institute for Health and Care Research) evaluated the effect of the VMS program and noted a reduction in medication-related incidents. Nevertheless, medication administration errors remain an important cause of patient harm. Therefore, information on ways to improve safe medication administration in hospitals is needed.

Table 1. Examples of medication administration errors

Medication administration errors	Example
Omission	Prescribed medicine was not administered
Wrong drug dosage	10 milligrams instead of 100 milligrams
Incorrect administration form	Suppository instead of a tablet
Decreased drug quality	Expired or an incorrectly stored medicine administered
Extra dosage	Extra dose of prescribed medication administered
Wrong drug	Lamictal® instead of Lamisil®
Wrong drug frequency	Daily instead of weekly (e. g. methotrexate)
Non-prescribed medicine	Giving a medication that is not prescribed
Wrong route of administration	Intramuscular instead of intravenous
Wrong technique of preparation	Suspension not shaken before administration, non- aseptic preparation
Wrong patient	Ms. XY instead of Ms. YX
Wrong speed of administration	(Smart)-pump incorrectly set (too fast, too slow)
Incompatibility of drugs	Preparations of iv antibiotics in Total Parenteral Nutrition or iv cefuroxime combined with aminoglycosides in the same syringe
Wrong time error	Given more than 1 hour before or after the prescribed time
Wrong administration technique	Forgotten to remove the air from the syringe before injection
Rapid intravenous bolus	Too rapid injection of a medication intended to be injected over a few minutes
Wrong solvent	Glucose 5% instead of sodium chloride 0.9% in the preparation of injections

SEARCH STRATEGY

In PubMed and Embase, we systematically searched for relevant literature with the following search strategy: ("Medication administration errors"[MeSH Terms] AND "Hospitals" [Title/Abstract]) AND ("Intervention" [All Fields]), supplemented by specific terms such as "Barcode","Aseptic Preparation","Wrong Time errors", "Epidemiology", "Labelling". We also systematically searched in PubMed and Embase with this search strategy: ("Medication safety" [Title/Abstract] AND "Medication administration" [All Fields] AND "Hospitals" [Title/Abstract]) AND ("Intervention" [MeSH Terms], supplemented by specific terms such as "Barcode", "Aseptic Preparation", "Time errors", "Dispensing", "Epidemiology", "Labelling". We searched back to 1990. Based on the publications found, we collected additional research papers.

SCALE AND IMPACT OF THE PROBLEM

In the most recent studies on medication administration errors in hospitalized patients, the average prevalence is 15.8% (range: 8.3%-24.8%) (Table 2). This range is probably due to differences in definitions (e.g., whether or not taking into account the time-window-errors), calculation of prevalence (different denominators can be used) and the error detection method. Tim-window-errors are sometimes excluded because they are considered less relevant. Settings may also differ between studies. Studies from Intensive Care Units and pediatric wards report a high prevalence probably due to errors in the preparation of injections and calculations of individual pediatric dosages [3]. Research carried out in the United Kingdom shows that 0.6% of medication administration errors in hospitals led to severe patient harm [4]. Although there is no clear hierarchy, medication with a narrow therapeutic index and intravenous administrations are considered to be particularly hazardous [5,6].

Table 2. Overview of the reviews on medication administration errors and results performed

First author; (reference)	Number of studies included (from – till)	Frequency of Medication administration errors including time errors * median; (range)	Frequency of Medication administration errors excluding time errors * median; (range)
Keers et al. (9)	91 (1985 – May 2013)	19.6% (8.6% -28.3%)	8.0% (5.1% - 10.9%)
Berdot et al.(12)	52 (1966 – December 2011)	25.2% (12.1% – 38.4%)	10.5% (7.3% - 21.7%)

* More than one error per medication administration possible

THE CAUSES OF MEDICATION ADMINISTRATION ERRORS

A systematic review of the causes of medication administration errors reports that these are often caused by unclear medication regulations, inadequate communication between nurses, miscommunication between medical doctors and nurses, drug supply problems, disruption of nurses during the medication rounds, unclear procedures, insufficient - whether or not competent - nursing staff and stress [7]. Patients also play a role: patients are asleep, are absent or unidentifiable because they do not wear a wristband or a wristband with proper identification [8,9].

STRATEGIES TO PREVENT MEDICATION ADMINISTRATION ERRORS

Overview

Research has been carried out worldwide on strategies to prevent medication administration errors [7,10]. The solutions which have been evaluated mostly are training, providing information, and process changes, with or without the use of information technology [11].

Training and providing information

A systematic review in which training programs for nurses have compared shows that training improves knowledge and skills, leading to a decrease in the number of medication administration errors [12]. The number of medication administration errors after giving various types of training (classical, presentations, self-study) decreased from 30.8% to 4.0%. However, the authors argue that based on these studies, there is no scientific evidence to determine which form of training or content contributes most to patient safety and a reduction in the number of medication administration errors [12]. In The Netherlands, the Health Care Inspectorate (Inspectie Gezondheidszorg en Jeugd, IGJ) supervises hospitals and sends them, based on incidents voluntarily reported to them or incidents observed by them, information to prevent future incidents. In 2015, for example, the IGJ sent warning letters to hospitals in The Netherlands about the preparation of Propofol® (risk of microbiological contamination) and the administration of once weekly dosages of methotrexate (risk of administration of daily dosages) in response to severe incidents involving the administration of these drugs to hospital inpatients.

Process changes without using information technology

There are several possibilities to change the process of drug administration, which may result in a safer administration of medication.

Preventing nurse disturbances

In a review of the association between the occurrence of disruptions in nurses administering medication and medication administration errors, measures such as wearing 'do-not-disturb' jackets or shirts during the medication rounds proved effective [13]. The total number of disruptions decreased from 50% to 34%. The total number of medication administration errors decreased from 16.6% to 2.0% and from 14.6% to 4.2% (after 12 months and 18 months respectively). Also in studies about (the effects of) nurse disturbances, there were large differences in the way the data was obtained, and different definitions were used [13,14]. Some measures, such as wearing the 'do-not-disturb' jackets

or shirts were perceived by more than half (52.3%) of the nurses as confusing, warm and difficult to wear [15]. Also, nurses considered it their task to be available for patients with questions. The 'do-not-disturb' jackets and shirts can become ineffective and even counterproductive over time [14].

Double-check

The double-checking system is in use in many hospitals during medication administration. A second nurse is involved in the medication preparation and administration process, especially of high-risk medications [11]. In practice, there is substantial variation in how the double-checking is carried out, for example, whether medication is checked independently by each of the nurses [16]. A capable patient can also perform an extra check when receiving medication [4]. Whether a 'double-check' can prevent medication administration errors is unclear because few quantitative studies have been carried out. In a review of 16 studies with only two quantitative studies involving medication errors, significant reductions in administration errors occurred from 29.8 to 21.2% and from 49 to 41% [17].

Labeling

Medication names can be very similar. The incorrect reading of labels that have the same appearance or similar names for the medication may be a cause of medication administration errors, for example, Lamictal® versus Lamisil®. Adjusting labels can contribute to safe medication administration, for example by writing LamicTAL® or LamiSIL®. However, there is insufficient evidence that this 'tall man lettering' is effective [18]. To prevent medication administration errors, the use of color-coded labels, with or without pictograms, has been introduced - especially in high-risk departments such as operating theatres and Intensive Care Units [19]. Again, evidence to support the introduction of this form of labeling throughout the hospital is scarce [20].

Preparation of medication by pharmacy technicians versus nurses

Preparation of intravenous medications by pharmacy technicians rather than nurses is effective in reducing the risk of contamination. Research in six Dutch hospitals showed large differences in the degree of bacterial contamination between syringes prepared by nurses in the 'clean workspace' on nursing wards and syringes prepared by pharmacy technicians in aseptic units of the hospital pharmacy [21]. More of the 650 syringes and ampoules prepared by nurses contained micro-organisms (median: 22%; range 7%-44%) compared to the syringes and ampoules that were prepared in the hospital pharmacy (infected with micro-organisms: 0%-1%, $P < .001$) [21]. Often, the 'clean workspace' in the nursing ward is not well equipped to prepare intravenously administered drugs.

Make or buy

Instead of preparing parenteral medication for administration, the purchase and supply of pre-filled syringes and bags ('prefilled syringes,' 'ready-to-use' or 'ready-to-administer') can prevent medication administration errors. These types of medication are mainly in use in high-risk departments as Intensive Care Units. There are no quantitative studies available that demonstrate the prevention of medication administration errors [22]. A study in five American hospital pharmacies shows that in 9% of intravenous preparations [23] errors occur. Buying ready-to-use medication may, therefore, be safer.

THE USE OF INFORMATION TECHNOLOGY

Smart infusion pumps

Intelligent infusion pumps ('smart-pumps') contain a software library of drugs to be used, with data for the usual dosage, dilution, and administration rate. Built-in alarms warn of erroneous data input or deviations outside the pre-programmed standards. Smart infusion pumps can reduce the high prevalence of administration errors in intravenous drugs (approximately 48%) [7]. Partly because of the price, these pumps are mainly used for the administration of high-risk medication and in high-risk departments. Although smart pumps may potentially contribute to patient safety, errors caused by incorrect use of the pump itself or the software have also been reported in a study [24]. Quantitative data on reduction of medication administration errors show mixed results, with, in general, no significant changes in the number of administration errors [24-27].

Barcoding

Scanning the barcode on the patient's wristband together with scanning the barcode on the drug to be administered ('bar-code-assisted medication administration' BCMA) makes it possible to maintain a so-called closed-loop system. The nurse scans the medicine and wristband at the patient's bedside, and this information is compared electronically with the prescribed medication in the electronic patient record. The administration data are recorded in the patient record in real time. Research shows that the number of medication administration errors (excluding time-window errors) after the introduction of BCMA decreased from an average of 8.6% to an average of 5.3% [28]. However, BCMA systems are not always used as intended, and so-called 'workarounds' occur [8]. These workarounds have been shown to be associated with medication administration errors [29].

Automated dispensing

Automated dispensing cabinets are sometimes used in high-risk departments. This method of working allows faster and safer administration of medication with fewer administration errors. However, the impact on administration errors seems to be small. The majority of the studies do not report any changes in the number of medication administration errors, but a single study shows a decrease in these errors from 8.9 to 7.2% [30]. There are also mobile automated dispensing cabinets which contain the entire medication ward stock in one trolley ('bedside assortment picking' BAP) which can be used for the medication round. Research in one hospital shows a decrease in medication administration errors from 1.65 to 0.84% [31].

NO RECOMMENDATIONS CAN BE MADE

Scientific research has been carried out in several countries on strategies to improve safety in the administration of medication in hospitals. The results of these studies are summarized in Table 3. The number of available studies is small, and most of them are single-site studies, carried out in one hospital only. Therefore, it is not possible to recommend the best strategies to be implemented in hospitals. However, the introduction of information technology seems promising [32,33].

Table 3. Summary of interventions

Intervention	First author; (reference)	Type of study	Effect of the intervention
Training	Harkanen et al. [12]	review	Reduction of medication administration errors of 30.8% - 4%, no type of training is preferred in this reduction
Preventing disturbances	Hayes et al. [13] Raban et al. [14] Westbrook et al. [15]	review review study	Reduction of disruptions of 50% - 34% and reduction of medication administration errors 16.6% - 2% and 14.6% - 4.2%, the effect disappeared, carrying jackets and shirts was considered difficult, warm and ineffective.
Double-check	Alsulami et al. [17] Schwappach et al. [16]	review study	In a limited number of studies in this review a reduction of administration errors 29.8% - 21.2% and 49% - 41%, much variance in the performance of the double-check
Labeling and label color codes	Lambert et al. [18] Merry et al. [22]	review review	Insufficient evidence for Tall Man Letting, color coding possible effective in reducing administration errors in anesthesiology
Aseptic preparation of injectable drugs in the central pharmacy	Grafhorst et al. [21]	study	More than 22% less bacterial contamination in prepared extemporaneous compounding in the hospital pharmacy versus extemporaneous compounding on the nursing ward
Pre-Filled-Syringes and Ready-To-Use preparations instead of extemporaneous compounding	Merry et al. [22]	review	Enhances medication safety by preventing extemporaneous preparation and by the bar-code on the labels
Intelligent intravenous pumps (smart pumps)	Ohashi et al. [24]	review	Reduction of medication administration errors in particular running-in speed but when in use, new errors were discovered (programming the pumps)
Bar-code medication administration	Hassink et al. [28]	study	Decrease in medication administration errors from 8.6% to 5.3% on average (excluding time-window-errors)
Automation / Robots	Cottney et al. [30] Ros, de Vreeze-Wesselink [31]	study study	A single study gives a reduction of medication administration errors from 8.9% to 7.2%, and in research, use of a BAP cart provides a reduction of administration errors from 1.65% to 0.84%.

THE STATUS QUO OF MEDICATION ADMINISTRATION IN HOSPITALS IN THE NETHERLANDS

Dutch hospitals use different ways to supply medication to hospitalized patients. These differences concern both the medication distribution system and the available information technology. Furthermore, hospitals used various strategies to prevent medication administration errors. The following are some examples illustrating this. Training and re-training for medical doctors and nurses highlighting the safety of the medication, including drug administration. Hospitals revised the protocols so that the preparation and administration of high-risk medication are subject to 'double-checking.' The VMS program offers some standard protocols for safe preparation and use of parenterally administered drugs. However, recent research shows that only a limited number of hospitals have implemented these standardized protocols [34]. Hospitals use smart infusion pumps in high-risk areas such as the operating theatre and the Intensive Care. Some hospitals use automated dispensing in high-risk departments, and a single hospital does this throughout the hospital. In commercial companies as well as in a few hospital pharmacies, robots make sterile preparations in the form of pre-filled syringes, intended for immediate use, and with a shelf-life of several weeks. Such compounding replaces the aseptic preparations done in the hospital pharmacy, satellite pharmacies or ward-based 'clean workspace,' which have a shelf-life of not more than 24 hours. In many Dutch hospitals, medications for individual patients are dispensed in the hospital pharmacy or ward-based satellite pharmacies and supplied in medication carts. Little comparative research has been carried out on the impact of the place of dispensing on administration errors. For example, the impact of central dispensing in the pharmacy versus dispensing in the ward-based satellite pharmacy. Again, we cannot provide conclusive evidence as to which method contributes most to medication safety. Information from the Dutch Hospital Pharmacists Association (Nederlandse Vereniging van Ziekenhuisapo-thekers, NVZA) shows us that BCMA at the bedside is taking place in eight Dutch hospitals. One of these hospitals uses the concept of Bedside-Assortment-Picking (BAP). The majority of hospitals use a manual recording of medication administration in the hospital information system. Some hospitals in The Netherlands work with electronic medication management systems with an integrated software program for prescribing, monitoring and administration of medication. One such system is MedEye and may be an interesting (partial) solution (https://nl.medeye.io/demo). This system consists of a small, portable box that scans each particular medication taken from the packaging at the patient's bedside. MedEye uses image recognition to check the medication and dosage. The MedEye-box contains software and a scanning system that recognizes, verifies and records medication in the patient record. This system is currently being piloted in four Dutch hospitals. MedEye is still too short 'on the market' to be able to make a scientific statement about the effect of the prevention of medication admin-

istration errors. Some hospitals in The Netherlands are experimenting with the patient's management of their medication (home prescribed by their family doctor, delivered by the local pharmacy and taken to the hospital at admission). The effect of this on medication administration errors has also not been investigated.

CONCLUSION

Medication administration errors occur daily in Dutch hospitals. There is much attention to preventing these errors. Interventions in the field of training (preparation of intravenous medications, training in introducing new techniques), process changes (do-not-disturb jackets, labeling) or the introduction of information technology (smart infusion pumps, bar-coded drug administration) have been developed or are still under development. There is only limited scientific evidence on the effectiveness of these strategies. Studies into effective ways to prevent medication administration errors are still needed.

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