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ORIGINAL RESEARCH

Introducing Unit Dose Dispensing in a University Hospital – Effects on Medication Safety and Dispensing Time

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Purpose: Unit dose (UD) medications reduce manual steps in the medication management and use process and enable electronic documentation by barcode scanning. This study aimed to explore the effects of introduced unit doses on medication safety and time spent on medication dispensing.

Patients and Methods: Direct before-and-after observations were conducted in an inpatient internal medicine ward at Helsinki University Hospital. The prevalence of medication and procedural errors and time nurses spent dispensing medications at patient-specific doses were observed 10 weekdays before and after introducing unit doses of selected medications. To complement the observations, a separate survey was used to investigate nurses' perceptions of medication dispensing. Quantitative analysis was performed.

Results: During the observations, medications were dispensed for 208 patients (n=1359 medications) before and 221 patients (n = 1171) after introducing unit doses. After UD implementation, 45.3% (n=530/1171) of the medications were dispensed as UDs. Medication and procedural errors were reduced (from 3.2% to 1.7% and 37.4% to 13.9%, respectively; $p<0.05$). Barcode scanning-related problems decreased from 21.4% to 1.8% ($p<0.05$) after implementation. The unit doses did not change the median time used to dispense medications to the patient, although the time used to dispense a single medication increased. In the survey, nurses reported improvements in barcode scanning but also indicated problems with handling unit doses and were worried about increased plastic waste.

Conclusion: Piloted unit doses decreased medication and procedural errors. Barcode scanning improved, which supported electronic closed-loop medication management in the study hospital. Unit doses in a fully automated process should be further studied for their effects on the dispensing time. In addition, controlling the amount of plastic waste in the unit dose dispensing should be considered.

Keywords: medication error, unit dose, automation, barcode scanning, medication systems, hospital, drug dispensing

Introduction

Medication management and use process in hospitals involve multiple steps during medicine prescribing, verifying orders, dispensing, administering, and monitoring.[1,2] All these phases are prone to medication errors (MEs), of which a remarkable proportion occurs in dispensing and administration of medicines.[3,4] To improve prospective risk management and safety and patient-specific dispensing, hospitals have implemented several automated solutions into their medication management and use processes.[5–9] Closed-loop electronic medication management systems (EMMS) represent such examples, and support safe administration by reliable and exact data transfers in real time.[10–12] In closed-loop EMMS, automation and technical solutions support safe and high-quality medication management and use process from prescribing to administration.[11] Closed-loop EMMSs include, eg, a computerized prescriber order entry, clinical decision support system, and barcode medication administration (BCMA) to support medication safety.[13] By minimizing preventable errors and ADEs with these technologies it is possible to enhance patient safety.[14]

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It is possible to produce ready-to-administer patient-specific doses using medication dispensing machines (eg, multidose and unit dose (UD) dispensing systems).[6,10,15] In multidose dispensing, medications are dispensed into patient-specific bags according to the administration time, and consequently, the bag often includes more than one medication. In UD dispensing, medications are repacked and labelled anonymously into single UDs by automated robots, usually in a hospital pharmacy. These UD bags can be further dispensed into patient-specific doses automatically in the hospital pharmacy or care units with technology assistance. Dispensing UD bags for patient-specific doses is a critical step in the medication management and use process.[16] During this step, the UDs are administered to one patient per administration time and are placed in a dose container or robotically combined. To improve safety, manual steps can be minimized by automation, and electronic medication documentation can be increased with technological solutions, such as barcode scanning or by radio frequency identification (RFID) technology.[17] To make these systems work properly, it is crucial that barcodes are available on medication packages. In UDs, the medication information and either a barcode or RFID are available for every single product, such as tablets, capsules, ampoules, and syringes.[18] In the administration phase, all the UDs are scanned to ensure safe administration.[9,11]

Different countries and hospitals are at very different stages in the automation of the pharmaceutical care process, and therefore the need for implementation studies is relevant. Some countries have not implemented any steps of the EMMS or have utilized only some parts of the system, and others have already utilized patient-specific UD dispensing combined with closed-loop EMMS to ensure safe and efficient medication management and use process.[18] It is important to gain information about what kind of benefits the implemented technologies actually produce or can produce and, on the other hand, what challenges they are associated with. The aim of this study was to explore the effects of the introduced UDs on medication safety and the time spent dispensing medication in a university hospital.

Materials and Methods

The present study, before and after observation, was conducted in an internal hospital ward with 24 patient beds at the Helsinki University Hospital. The hospital accommodates 3000 beds and provides tertiary and secondary care in the capital area of Finland. Patients with acute and chronic somatic diseases, as well as infections, were treated in the study ward. In the present study, medication errors (MEs) and procedural errors (PEs) comprised the outcome measures for medication safety. The prevalence of errors and medication dispensing times were observed before and after introducing the selected medications in the UD bags (Figure 1). Patient information was not collected during this study. Errors in the dispensing phase were classified as MEs if they included incorrect patient, medication, dose, time, order, or medication omission. In PEs, nurses did not follow the hospital's protocol, eg, hygiene instructions or barcode scanning, in the

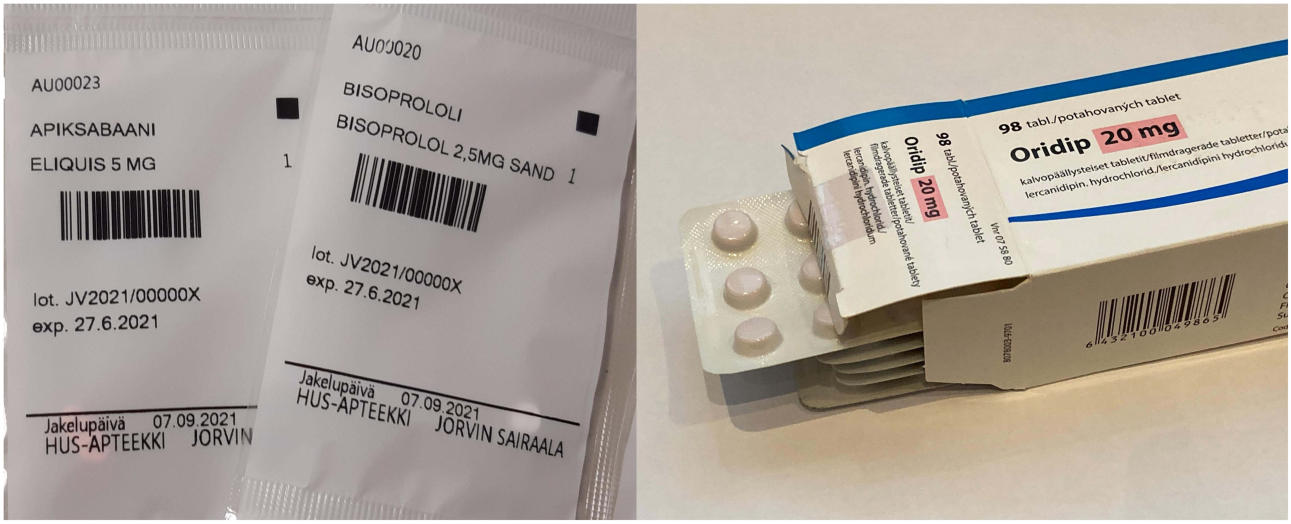

Figure 1 Examples of anonymously packed unit dose medications produced in the hospital pharmacy using Baxter FDS Proud 260 (examples on the left side). Before implementation all the medications were dispensed from the secondary packages (example on the right side).

dispensing process. Additionally, nurses' perceptions of the dispensing process before and after the implementation of UDs were anonymously surveyed to complement the data from the observations and gather experiences about the feasibility of UDs. The frequency distribution of open-ended questions was evaluated.

Dispensing Process Before Introducing Unit Doses

In the study ward, orders were entered into the electronic health record (EHR) (Apotti, EPIC-based system) supported by clinical decision support (Figure 2). Medications were distributed from the hospital pharmacy to the ward and stored and dispensed in patient-specific doses from the ward's automated dispensing cabinet (ADC, Pyxis MedStation™), which has an interface with the EHR. Patient-specific dispensing was conducted by nurses in the ward's medical rooms. Before the pilot, all products were stocked in their secondary packages (ie, the original commercial pack) in the ward's ADC. For medication dispensing and administration, the ward used patient-specific barcodes. Before dispensing, patient-specific barcodes were printed from the EHR and attached to the patients' medicine beaker(s) for oral solid formularies or to the original pack for medications ready to administer (such as syringes, inhalators, powder sachets, and eye drops). Subsequently, the barcodes of the secondary packages of the dispensed medicines and the label in the beaker were scanned to ensure that the right medication was dispensed to the right patient. At the bedside of the patient during the administration phase, the patient-specific barcode attached to the dispensed medications was scanned together with the patient's wristband to identify the patient, ensure that the right medication was administered to the right patient, and the administration was recorded electronically (BCMA).

Dispensing Process After Introducing Unit Doses

In this study, the individually packed UDs of the selected medications replaced the secondary packages of these products in the study ward (Figure 2). The UDs were anonymous as they did not contain any patient information. The UDs were placed in the ADCs of the ward. Only high consumption, orally administrated, and solid products were selected for UD packing as they were able to be dispensed to UDs by the hospital pharmacy dispensing machine without stability or contamination issues. The rest of oral solid products as well as liquids and parenteral products were dispensed in the same way before and after introducing UDs. The selection process for the UD products is shown in Figure 3.

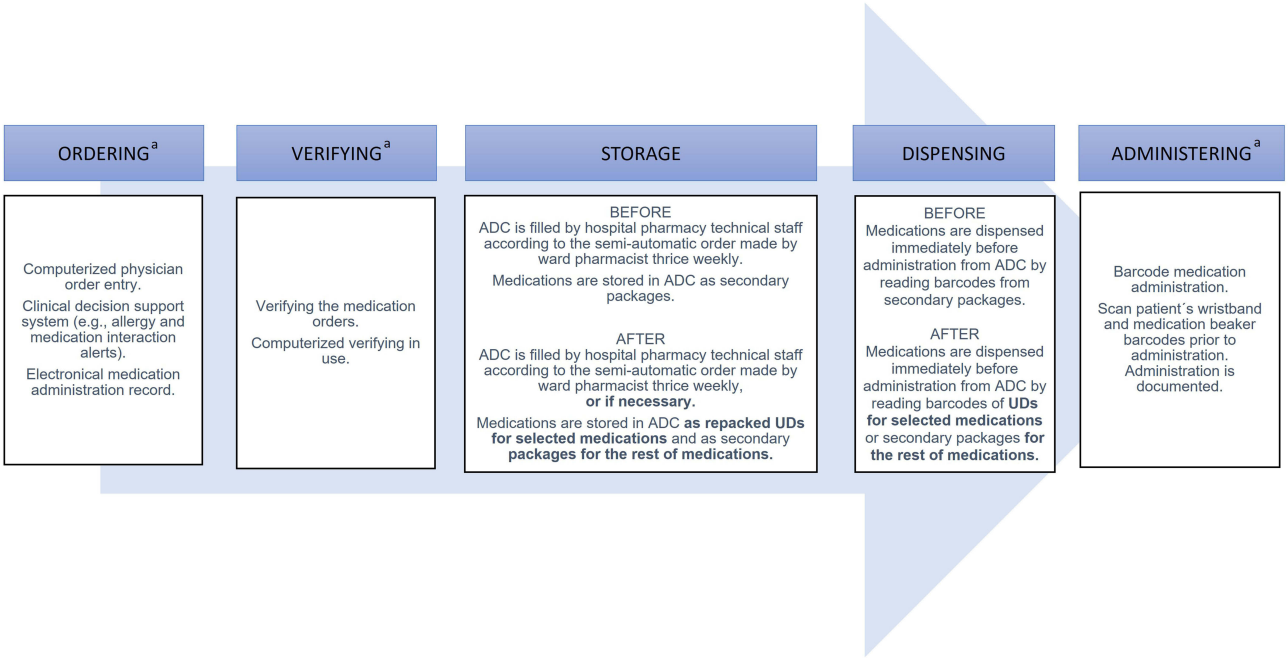

Figure 2 The medication management process before and after implementing unit doses (UDs) on the study ward. Changes were made only to storage and dispensing phases, and they are marked as bolded text. ADC = automated dispensing cabinet; [a]No changes before and after implementation of UDs.

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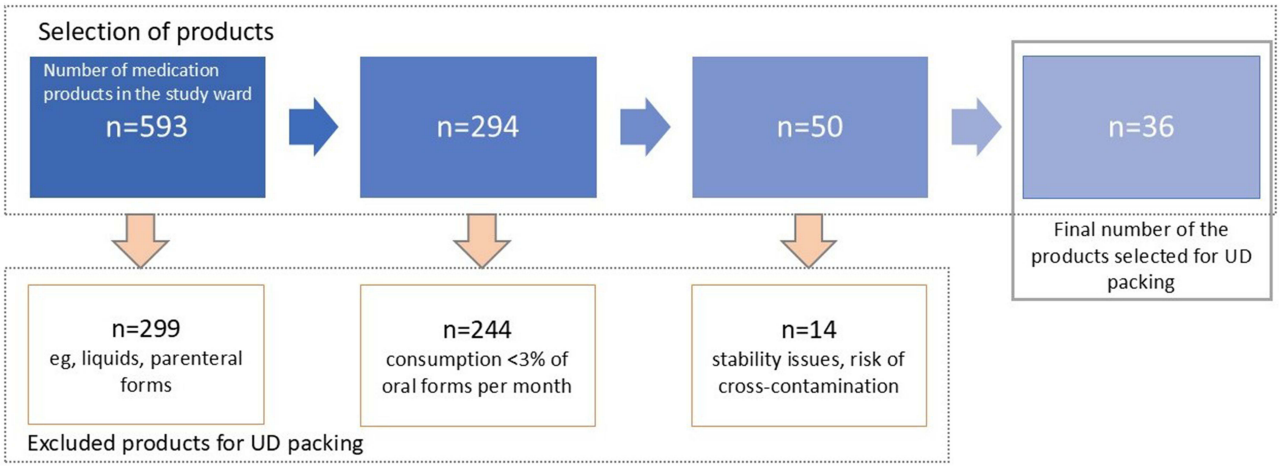

Figure 3 Selection of products for unit dose (UD) packing. All the products used by the study ward (n=593) were not dispensed in UDs as they had small consumption or were not suitable for UD packing because of 1) formulation (eg, dispersible, effervescent, or chewable tablets, liquids and parenteral forms) or 2) risk of cross-contamination (eg, anti-infective medications, hormones, immunomodulating agents).

The implementation of the UDs was conducted gradually, and the process was altered as needed. UDs were produced in the hospital pharmacy using the Baxter FDS Proud 260, and bags were delivered to the study ward three times weekly or every weekday, if required. The nursing staff was informed about piloting UDs and educated on handling and opening UD bags.

Data Collection Through Observation

An outline of these observations is shown in Figure 4. The baseline observation was completed during August and September 2021 before introducing the UDs to the study ward. Two professionals (HA and the clinical pharmacist of the ward) observed nurses dispensing patient-specific morning medication doses for all patients in the ward, using ADC and barcode scanning. Based on previous studies, a sample of >1000 dispensed medications before and after UD implementation was estimated to show a statistical difference in observed errors and dispensing time.[19,20] The number of morning medications was estimated to be five for each patient, and the study ward accommodated 24 beds; 10 days was chosen as an adequate length for the observation period. During the observation period, the following outcome measures were documented in a structured observation form developed by the researchers (Appendix 1): time spent on medication dispensing (start and end times), identified MEs (wrong patient, medication/formulation, dose, order, time errors, and omission), and PEs (lack of following hygiene instructions, deviation from using barcodes, hospital protocol not followed when the medication change was conducted, and others). Patient information was not collected in this study. The observation form was pilot tested before the first observation. If MEs (wrong patient, dose, or drug) were identified during observation, the nurse was informed, and errors were corrected before administration to the patient.

Complementary Survey

A separate survey targeting nurses (n=25) in the study ward was conducted over a 2-week period in September 2021 before implementing UDs. The survey was repeated in December 2021, after the implementation of the UDs (Figure 4). In the beginning of the survey, there was information about the study and research number and it was informed that answering the survey was voluntary, anonymous and confidential. The survey was adapted from Zaidan et al (2016) study on ADCs and was developed to focus on our specific interests.[21] It was initially piloted by a nurse from the study ward, and modifications were made based on the feedback to create the final version using Microsoft Forms. The survey (Appendix 2) was distributed electronically via email, and two reminders were sent before the due date. The survey covered structured questions on nurses' characteristics, including work experience in the care unit and with the ADC; structured questions with a 5-point Likert scale exploring the perceptions of the responding nurses on the safety of the medication management and use process; and open-ended questions about strengths, challenges, and targets for improvement in the dispensing process.

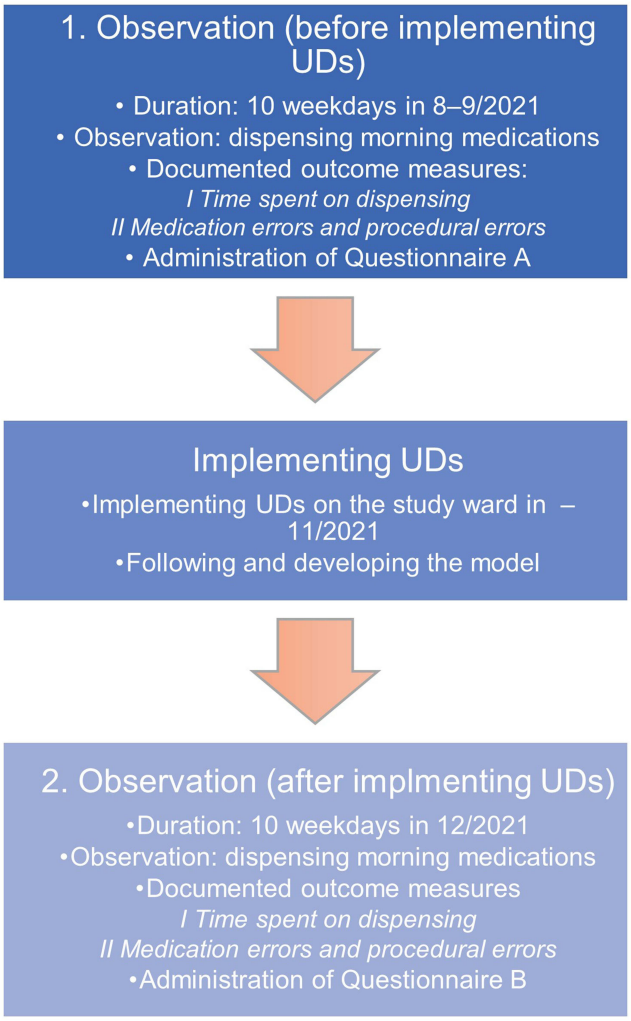

Figure 4 Outline of the observation phase of the study before and after implementing unit doses (UDs).

Data Analysis

The data from the observation forms were imported into Microsoft Excel. The data collected on MEs, PEs, and dispensing time were analyzed and compared before and after the pilot using the chi-square test and *t*-test ($p < 0.05$) using IBM SPSS Statistics Version 25. Data at smaller frequencies were analyzed using Fisher's exact test. Structured data from the survey were analyzed using descriptive statistics (frequencies in numbers and percentages). Data from open-ended questions were categorized using Microsoft Excel 365, and the frequency distribution was reported.

Ethical Approval

This study was approved by the Helsinki University Hospital Research Center (chief medical officer, HUS/182/2021). Based on the national guidelines and consultation with the Committee on Medical Research Ethics at HUS, ethical approval was not required, as the study did not contain any patient data.[22] Nursing staff had been informed before the study, and participation of nurses was voluntary. Written informed consent was not obtained from the participants as the ethical committee did not require it in this study.

Results

During the observation period, morning medications were dispensed to 208 patients (n=1359) before and 221 patients (n=1171) after introducing UDs in the study ward (Table 1). After UD implementation, 45.3% (n=530/1171) of the

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Table 1 Characteristics of Medication Dispensing for 10-Day Observations Before and After Implementing Unit Doses (UDs)

	1. Observation (before implementing UDs)	2. Observation (after implementing UDs)	P for *T* test or χ^2
Observation days (n)	10	10	–
Number of patients (n)	208	221	–
Total number of medications dispensed (n)	1359	1171	–
Mean number of medications dispensed per morning (median; range min–max)	136 (139; 110–155)	117 (117; 84–151)	0.029[a]
Mean number of medications dispensed per patient per morning (median; range min–max)	6.5 (6; 1–16)	5,3 (5; 1–13)	<0.000[a]
Mean time used to dispense medications per day in minutes (median; range min–max)	95 (91; 76–127)	92 (93; 61–118)	NS
Calculated mean time/patient in minutes (median, range min–max)	4:35 (4:17; 3:15–8:06)	4:10 (4:23; 2:37–5:33)	NS
Calculated mean time/medication in minutes (median; range min–max)	0:42 (0:41; 0:33–1:01)	0:48 (0:47; 0:37–1:02)	0.021[a]
Errors (n, % of the medications dispensed)	553 (40.7%)	183 (15.6%)	<0.000[ab]
Medication errors (n, % of medication dispensed)	44 (3.2%)	20 (1.7%)	0.015[ab]
Procedural errors (n, % of medication dispensed)	509 (37.5%)	163 (13.9%)	<0.000[ab]

Notes: [a]P-value <0.05, [b]χ^2 test.
Abbreviation: NS, non-significant.

medications were dispensed as UDs. Errors, comprising both MEs and PEs, occurred in 40.7% (n=553/1359) of the dispensed medications before implementation and 15.6% (n=183/1171) after introducing UDs, showing a significant reduction (p<0.05). The mean time used for daily dispensing did not significantly change between observations, whereas the calculated mean time per medication increased by 6 s (Table 1).

Medication Errors (MEs)

MEs decreased significantly from 3.2% to 1.7% (p=0.015; Table 2) with the use of UDs. The wrong order was the most frequently observed error type, which decreased significantly after UD implementation (from 1.6% to 0.5%, p<0.05).

Table 2 Number and Frequency of Subtypes of Medication Errors for Both Observation Periods

Error type	1. Observation (before implementing UD dispensing)		2. Observation (after implementing UD dispensing)		P for Fisher's exact (or χ^2)
	n	%[a]	n	%[a]	
Medication errors	44	3.2	20	1.7	0.015b[c]
Wrong patient	0	0.0	0	0.0	N/A
Wrong medication	3	0.2	5	0.4	NS
Wrong dose	3	0.2	0	0.0	NS
Wrong administration time	11	0.8	5	0.4	NS[c]
Omission of dose	5	0.4	4	0.3	NS
Wrong order	22	1.6	6	0.5	0.008[bc]

Notes: [a]Percentage of errors/medications dispensed (1. Observation n=1359; 2. observation n=1171), [b]P-value <0.05, [c]χ^2 test.
Abbreviations: UD, unit dose; N/A, not available; NS, non-significant.

According to observational data, these errors were mainly linked to inadequate use of the hospital's medication formulary. For other error types, including incorrect patient, medication, dose, administration time, or omission of dose, a statistically significant reduction was not achieved as a result of UD implementation.

Procedural Errors (PEs)

PEs (ie, deviation from a hospital's protocol in the dispensing process) significantly decreased from 37.5% to 13.9% ($p<0.05$, Table 3) when using UDs. Before introducing UDs, the majority of PEs were barcode-related errors (eg, barcode was not scanned as it was missing, or scanning was performed from an unattached piece of paper instead of a secondary package). With UDs, the barcode-related errors decreased significantly (from 21.4% to 1.8%). Errors in not following hygiene instructions also decreased after the implementation of UDs, as direct contact with medications was more often avoided. However, "other" error types increased (from 2.1% to 3.6%), as there were technical problems with the integration of EHR and ADC for two UD products, acetylsalicylic acid and vitamin D tablets. The problem with acetylsalicylic acid tablets was solved during the second observation, but the reason for the technical issues associated with vitamin D tablets remained unknown.

Nurses' Perceptions on UD Dispensing

Of the 25 nurses working on the ward's dispensing process, 56.0% (n=14) provided a comprehensive reply to the survey before and 48.0% (n=12) after UD implementation. Barcodes were reported as always being scanned from the original package, according to 7.1% of nurses (n=1/14) who had participated in medication dispensing before (1. survey) and 83.3% (n=10/12) after introducing UDs (2. survey). In addition, 50.0% of nurses (n=6/12) reported that barcodes were easier to scan in UDs than in secondary packages.

All nurses who responded to the first survey reported that hygiene instructions were always or often followed in medication dispensing before introducing UDs. In the second survey, hygiene instructions were reported to always or often be followed by 75.0% (n=9/12) of the answers.

In the second survey, the majority of responding nurses (83.3%, n=10/12) reported that UDs were difficult to handle (bags were difficult to remove from the ADC, bags were easily broken, and static electricity made them difficult to

Table 3 Number and Frequency of Subtypes of Procedural Errors for Each Period

Error type	1. Observation (before implementing UD dispensing)		2. Observation (after implementing UD dispensing)		P for χ^2
	n	%[a]	n	%[a]	
Procedural errors	509	37.5	163	13.9	<0.000[b]
Limitations in barcoding	292	21.5	21	1.8	<0.000[b]
Unattached barcode	250	18.4	0	0.0	<0.000[b]
Missing barcode	42	3.1	21	1.8	0.037[b]
Deviationfollowing hygiene instructions	186	13.7	99	8.5	<0.000[b]
Direct contact with medications (unclean, bare hands)	126	9.3	40	3.4	<0.000[b]
Unclean spoon or tweezers	18	1.3	23	2.0	NS
Unclean pill-splitter	40	2.9	36	3.1	NS
Not known	2	0.1	0	0	NS
Deviated from prescription by ward's own procedure	2	0.1	1	0.1	NS
Other	29	2.1	42	3.6	0.027[b]

Notes: [a]errors/medication dispensed (1. observation n=1359; 2. observation n=1171); [b]p <0.05.
Abbreviations: UD, unit dose; NS, non-significant.

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empty). However, they reported that it was easy to find UD medications in ADC always or often (91.7%, n=11/12). Some nurses (25.0%, n=3/12) reported that dispensing was slower with UDs bags and that UD bags needed more space to store. Split tablets in UD bags have been reported to result in faster dispensing (16.7%, n=2/12). Furthermore, nurses were worried about the large amount of plastic waste created by the UDs (66.7%, n=8/12).

Discussion

Introduced UDs improved medication safety through increased barcode scanning. However, the time spent on dispensing medication did not decrease as the UDs were dispensed by nurses from the ADCs.

Effects of Unit Dose Dispensing on Medication Safety

In the present study, UD implementation significantly decreased both MEs and PEs. In particular, UDs increased the safety of medication dispensing by improving barcode scanning, which is in line with earlier studies.[23,24] However, in previous studies, scanning has been mainly explored in the administration phase and not in the dispensing phase, as in this study. Barcode scanning, both in the dispensing and administration phases, is an important defense in medication management and use process to strengthen closed-loop EMMS.[15] Barcode scanning can minimize dispensing and administration errors.[23,24] To ensure appropriate scanning, barcodes should always be available in medication products. If barcodes are missing (eg, blisters without barcodes in the original packages in the ADC), there is a greater opportunity for errors. Although UD packaging is an effective method for enhancing barcode scanning, the pharmaceutical industry should provide more barcodes on primary packages. Additionally, the availability of barcodes in primary packages should be prioritized in the medication formularies of hospitals. Furthermore, to gain the maximum benefit from EMMS, nurses must understand the role of barcode scanning as a key systemic defense against medication dispensing errors.[25] It is important to provide education to nurses to increase their knowledge about scanning and system-based medication risk management.

By implementing UDs, the MEs decreased from 3.2% to 1.7%, which was statistically significant. A reduction in MEs was achieved, although some medications, such as anti-infectives, chewable tablets, ampoules, syringes, and other small consumption and oral forms remained outside UD dispensing. This indicates that implementing UD dispensing, even partially, may improve safety, to some extent. However, the existing different types of UD dispensing models make the comparison of the present results in earlier studies complex.[18–20,26] Cousein et al studied MEs in the UD dispensing system, and they found a 5.0% ME rate, as omission of a dose occurred more often than in our study (4.1% vs 0.3%).[19] In which medications were automatically dispensed patient-specific for 24-hours, contrary to our study where nurses dispensed doses from ADC according to EHR medication administration records in a timely manner; a maximum of 2 h before administration to the patient. Furthermore, in our process, the EHR reminded nurses if a dose was missing or incorrectly dispensed, which may explain the lower omission error rate. Recent studies have also shown ME reduction in fully automated systems.[18,26,27] However, the results of these studies are not comparable to those of our study, where the hospital UD automation was not fully automated and only in its pilot phase.

The wrong order was the most common error type in both observations, and these errors decreased significantly after implementing the UDs. This was surprising because implementing UDs does not have a direct impact on the ordering phase, as the process for physicians is similar whether there are UDs in use or not. Most ordering errors are related to non-formulary orders. The reason for the decreased ordering errors might be due to increased attention to following the formulary because these errors were noticed and corrected in the first observation period. Hence, physicians were informed by the ward pharmacist about these errors, and consequently, similar errors might have often been avoided in the second observation. Currently, the EHR clinical decision support system does not assist physicians in the following the hospital's formulary in an optimal way. In the ordering phase, it is not possible to determine which product is in the formulary or available in the ward's ADC. Verification of orders is a crucial step in EMMS because the next steps in the medication process rely on correct orders.[15] Internationally, non-formulary orders are typically verified and checked by pharmacists, but computerized auto-verification is also applied.[28,29] However, optimization of auto-verification should also take place together with the systematic addition of more pharmaceutical verification into the process. These practices may have the potential to correct prescribing errors and increase the safety of the ordering process.

Improved Adherence to Hygiene Instructions

In addition to enhanced barcode scanning, contact between the bare hands and medications (procedural error) was significantly reduced after implementing the UDs. This comprises a positive outcome, as improving adherence to hygiene instructions and right dispensing practices is warranted in hospitals for hygiene and safety reasons.[30] Some medications, such as chemotherapeutic agents or immunosuppressants, should always be handled with specific care, as active substances may cause harm to the person dispensing medications or to other patients.[31] Consequently, adherence to hygiene instructions and good dispensing hygiene contribute to both medication safety and occupational safety, which are central components of high-quality care. However, further research is needed to determine how UDs affect dispensing hygiene. The first survey administered at the time of UD implementation may have affected nurses, who might have become more aware of hygiene instructions.

Effects on Time Spent on Medication Dispensing

In this study, no change in the morning medication dispensing was detected after the implementation of UDs. The time spent on UD medication dispensing has not been widely studied, and most recent studies have analyzed fully automated UD systems, in which dispensing was completed robotically.[18] In our study, approximately the same time was used for morning medication dispensing before and after implementation, and dispensing time per patient was slightly faster during the second observation. However, the time required to dispense a single medication has significantly increased. Furthermore, fewer medications per patient were dispensed during the second observation period, which explains some of these changes. Using ADC has some time-consuming phases that must be done to determine whether one or more drugs are dispensed; for example, patients' medication administration records in EHR must be opened before dispensing the first medication. However, in our study, with this delay in dispensing time per medication, the medication safety was increased by improved barcode scanning.

In this pilot study, nurses dispensed patient doses. To save nurses' time for dispensing, fully automated, patient-specific medication dispensing systems should be implemented.[18,27] This is the main goal of our study hospital. The current shortage of nurses is a well-recognized problem in Finland and internationally.[32,33] Saving the time that nurses spend dispensing medication and freeing it up for other nursing activities is an important development target for high-quality care.

Challenges in Unit Dose Implementation

Although EMMS brings safety into the medication management and use process, new safety risks may also appear, and technological issues must be solved during implementation.[34] In this pilot, we found technical problems between ADC and EHR considering some UD items: vitamin D and acetylsalicylic acid tablets causing extra work for nurses in the dispensing phase. Solving technical problems requires time and resources, which must be considered before the UD system's implementation.[5,34]

In the second survey, after implementing UDs bags, nurses were worried about the amount of plastic waste related to UD bags. However, one plastic beaker with a lid weighed approximately the same as the three UD bags. While nurses tended to use one to three beakers per patient, the amount of plastic waste was rather similar. However, the size of UD bags should be optimized in the future. While we were unable to find earlier studies that considered UD dispensing and plastic waste, the sustainable implementation of UD dispensing represents a key target for future research. This is crucial, as the increased amount of plastic waste produced by healthcare is acknowledged to harm the environment.[35] Consequently, some have suggested that hospitals should improve recycling of their plastic waste.[36] Empty UD bags are an example of non-infected, one component plastic waste that could be easily collected in hospitals for recycling. Furthermore, the use of biodegradable materials in UD process should be investigated.

Limitations

In the present study, only some solid morning medications (36/294, 45.3% of morning medication consumption) were delivered to the ward, as in UDs. However, significant improvements in medication safety were observed. In addition, medication dispensing was conducted by nurses and automation was not utilized in patient-specific dispensing, which is considered to save time in dispensing.[14] Without automation, medication dispensing is conducted by nurses in a ward regardless of whether UDs are applied or not.

Patients received fewer medications during the second observation period. However, the risk of bias was estimated to be small because medication and procedural errors did not depend on the number of medications for each patient. However, the differences between these groups may have affected the time taken to dispense medications by slowing down the process.

Conclusion

The implemented UDs improve medication safety by reducing medication and procedural errors. Barcode scanning during the dispensing process also improved, which supports the establishment of closed-loop medication management and use process in the study hospital. UDs in a fully automated dispensing process should be studied further to determine their effects on the dispensing time. In addition, controlling and reducing the amount of plastic waste should be considered in the UD model implementation.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Kohn KT, Corrigan JM, Donaldson MS. *To Err Es Human: Building a Safer Health System. ISBN-10: 0-309-06837-1*. Washington DC: National Academy Press; 2000.
2. WHO. Medication without harm – WHO global patient safety challenge on medication safety. Geneve: WHO 2017. Available from: http://apps.who.int/iris/bitstream/handle/10665/255263/WHO-HIS-SDS;jsessionid=2F729E4033DF6CACA051BC58BF4C739F?sequence=1. Accessed April 10, 2023.
3. Härkänen M, Turunen H, Saano S, Vehviläinen-Julkunen K. Detecting medication errors: analysis based on a hospital's incident reports. *Int J Nurs Pract*. 2015;21(2):141–146. doi:10.1111/ijn.12227
4. Holmström A-R, Järvinen R, Laaksonen R, Keistinen T, Doupi P, Airaksinen M. Inter-rater reliability of medication error classification in a voluntary patient safety incident reporting system HaiPro in Finland. *Res Social Adm Pharm*. 2019;15(7):864–872. doi:10.1016/j.sapharm.2018.11.013
5. Ahtiainen HK, Kallio MM, Airaksinen M, Holmström A-R. Safety, time and cost evaluation of automated and semiautomated drug distribution systems in hospitals: a systematic review. *Eur J Hosp Pharm*. 2020;27(5):253–262. doi:10.1136/ejhpharm-2018-001791
6. Batson S, Herranz A, Rohrbach N, Canobbio M, Mitchell SA, Bonnabry P. Automation of in-hospital pharmacy dispensing: a systematic review. *Eur J Hosp Pharm*. 2021;28(2):58–64. doi:10.1136/ejhpharm-2019-002081
7. Fung EY, Leung B, Hamilton D, Hope J. Do automated dispensing machines improve patient safety? *Can J Hosp Pharm*. 2009;62(6):516–519. doi:10.4212/cjhp.v62i6.852
8. Kuiper S, McCreadie S, Mitchell J, Stevenson J. Medication errors in inpatient pharmacy operations and technologies for improvement. *Am J Health-Syst Pharm*. 2007;64(9):955–959. doi:10.2146/ajhp060267
9. Metsämuuronen R, Kurttila M, Naaranlahti T.Automaation hyödyntäminen sairaaloiden lääkehuollossa nyt ja tulevaisuudessa [The utilisation of automation in medicine supply process in hospitals – now and in the future]. *Dosis*. 2018;34(2):104–119.
10. Franklin BD, O'Grady K, Donyai P, Jacklin A, Barber N. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: a before-and-After study. *Qual Saf Health Care*. 2007;16(4):279–284. doi:10.1136/qshc.2006.019497
11. Zheng WY, Lichtner V, Van Dort BA, Baysari MT. The impact of introducing automated dispensing cabinets, barcode medication administration, and closed-loop electronic medication management systems on work processes and safety of controlled medications in hospitals: a systematic review. *Res Social Adm Pharm*. 2021;17(5):832–841. doi:10.1016/j.sapharm.2020.08.001

12. Shermock SB, Shermock KM, Schepel LL. Closed-loop medication management with an electronic health record system in U.S. and Finnish hospitals. *Int J Environ Res Public Health*. 2023;20(17):6680. doi:10.3390/ijerph20176680
13. Liu HC. *Healthcare Risk Management From a Proactive Perspective. Improved FMEA Methods for Proactive Healthcare Risk Analysis*. Singapore: Springer; 2019. 3–13. doi:10.1007/978-981-13-6366-5_1
14. Risør BW, Lisby M, Sørensen J. Cost-effectiveness analysis of an automated medication system implemented in a Danish hospital setting. *Value Health*. 2017;20(7):886–893. doi:10.1016/j.jval.2017.03.001
15. Bhatti S. Adoption of closed loop medicines administration into the NHS. The Pharmaceutical Journal; 2019. Available from https://pharmaceutical-journal.com/article/opinion/adoption-of-closed-loop-medicines-administration-into-the-nhs. Accessed September 2, 2024.
16. James KL, Barlow D, McArtney R, Hiom S, Roberts D, Whittlesea C. Incidence, type and causes of dispensing errors: a review of the literature. *Int J Pharm Pract*. 2009;17(1):9–30. doi:10.1211/ijpp.17.1.0004
17. Hwang Y, Yoon D, Ahn EK, Hwang H, Park RW. Provider risk factors for medication administration error alerts: analyses of a large-scale closed-loop medication administration system using RFID and barcode. *Pharmacoepidemiol Drug Saf*. 2016;25(12):1387–1396. doi:10.1002/pds.4068
18. Hänninen K, Ahtiainen H, Suvikas-Peltonen E, Tötterman AM. Automated unit dose dispensing systems producing individually packaged and labelled drugs for inpatients: a systematic review. *Eur J Hosp Pharm*. 2023;30(3):127–135. doi:10.1136/ejhpharm-2021-003002
19. Cousein E, Mareville J, Lerooy A, et al. Effect of automated drug distribution systems on medication error rates in a short-stay geriatric unit. *J Eval Clin Pract*. 2014;20(5):678–684. doi:10.1111/jep.12202
20. Taxis K, Dean B, Barber N. Hospital drug distribution systems in the UK and Germany-a study of medication errors. *Pharm World Sci*. 1999;21(1):25–31. doi:10.1023/a:1008616622472
21. Zaidan M, Rustom F, Kassem N, et al. Nurses' perceptions of and satisfaction with the use of automated dispensing cabinets at the Heart and Cancer Centers in Qatar: a cross-sectional study. *BMC Nurs*. 2016;15(4):1–8. doi:10.1186/s12912-015-0121-7
22. Finnish National Board on Research Integrity (TENK). The ethical principles of research with human participants and ethical review in the human sciences in Finland. Finnish national board on research integrity TENK guidelines 2019. Available from: https://tenk.fi/sites/default/files/2021-01/Ethical_review_in_human_sciences_2020.pdf. Accessed September 22, 2024.
23. Jessurun JG, Hunfeld NGM, Van Rosmalen J, Van Dijk M, Van Den Bemt PMLA. Effect of automated unit dose dispensing with barcode scanning on medication administration errors: an uncontrolled before-and-after study. *Int J Qual Health Care*. 2021;33(4):1–8. doi:10.1093/intqhc/mzab142
24. Poon EG, Keohane CA, Yoon CS, et al. Effect of bar-code technology on the safety of medication administration. *N Engl J Med*. 2010;362(18):1698–1707. doi:10.1056/NEJMsa0907115
25. Oldland AR, Golightly LK, May SK, Barber GR, Stolpman NM. Electronic inventory systems and barcode technology: impact on pharmacy technical accuracy and error liability. *Hosp Pharm*. 2015;50(1):34–41. doi:10.1310/hpj5001-34
26. Risør BW, Lisby M, Sørensen J. An automated medication system reduces errors in the medication administration process: results from a Danish hospital study. *Eur J Hosp Pharm*. 2016;23(4):189–196. doi:10.1136/ejhpharm-2015-000749
27. Risør BW, Lisby M, Sørensen J. Complex automated medication systems reduce medication administration errors in a Danish acute medical unit. *Int J Qual Health Care*. 2018;30(6):457–465. doi:10.1093/intqhc/mzy042
28. Chang E, Kinkade A, Tung ACH, Tejani AM. Going through the motions: a time-and-motion study of workload associated with nonformulary medication orders. *Can J Hosp Pharm*. 2017;70(2):133–137. doi:10.4212/cjhp.v70i2.1646
29. Pedersen CA, Schneider PJ, Ganio MC, Scheckelhoff DJ. ASHP national survey of pharmacy practice in hospital settings: prescribing and transcribing—2019. *Am J Health Syst Pharm*. 2020;77(13):1026–1050. doi:10.1093/ajhp/zxaa104
30. Spivey P. MDS-3 Managing Access to Medicines and Health Technologies. Embrey M, Ryan M, editors. In: *Ensuring Good Dispensing Practices*. Arlington: Management Sciences for Health; 2012. 30.1–17. https://msh.org/wp-content/uploads/2014/01/mds3-jan2014.pdf.: Accessed November 3, 2023.
31. Goodin S, Griffith N, Chen B, et al. Safe handling of oral chemotherapeutic agents in clinical practice: recommendations from an international pharmacy panel. *J Oncol Pract*. 2011;7(1):7–12. doi:10.1200/jop.2010.000068
32. Haddad LM, Annamaraju P, Toney-Butler TJ. Nursing Shortage. Treasure Island (FL). StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK493175/. Accessed April 10, 2023.
33. TEM. Occupational Barometer: increase in labour shortages has slowed down but health and social services continue to account for top shortage occupations. Ministry of Economic Affairs and Employment (Finland) Press release 2022. Available from: https://tem.fi/en/-/occupational-barometer-increase-in-labour-shortages-has-slowed-down-but-health-and-social-services-continue-to-ac-count-for-top-shortage-occupations. Accessed February 7, 2023.
34. Lindén-Lahti C, Kivivuori S-M, Lehtonen L, Schepel L. Implementing a new electronic health record system in a university hospital: the effect on reported medication errors. *Healthcare*. 2022;10(6):1020–1032. doi:10.3390/healthcare10061020
35. Rizan C, Mortimer S, Stancliffe R, Bhutta MF. Plastics in healthcare: time for re-evaluation. *J R Soc Med*. 2020;113(2):49–53. doi:10.1177/0141076819890554
36. Blessy J, Jemy J, Nandakuman K, Sabu T. Recycling of medical plastics. *Adv. Ind. Eng. Polym. Res.* 2021;4(3):199–208. doi:10.1016/j.aiepr.2021.06.003