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A comprehensive study of prescribing, administering and drug handling medication errors in ten wards of a university hospital after implementation of electronic prescribing, clinical pharmacists or medication reconciliation

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Received May 26, 2023, accepted January 15, 2024

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Pharmazie 79: 11-16 (2024) *doi: 10.1691/ph.2024.3579*

Background and aim: Medication errors lead to preventable risks. Preventing strategies such as e-prescribing, clinical pharmacists and medication reconciliation have been implemented in recent years. However, information on long-term medication error rates in routine procedures is missing. *Investigations:* We aimed to identify predefined medication errors in ten wards of a university hospital where e- prescribing, clinical pharmacists and medication reconciliation have been partially implemented. Patient files were reviewed and routine processes were monitored for drug prescription errors (missing, unclear, outdated information), administration errors (wrong dispensed drugs) and drug handling errors (no light-, moisture-protection, wrong splitting, no separation of drugs, which ought to be taken by an empty stomach). *Results:* We analyzed 959 prescriptions with 933 solid peroral drugs for 182 patients (98 female, median age 66.5 years [Q25-Q75: 56-78 years]; the median number of drugs was 5 [Q25-Q75: 3-7]). The most frequent prescription error was a not specified drug form (91.1%). The most common administration error was a not adequately provided release dose formulation (72.7%). The lack of light protection for observed photosensitive drugs was the most frequent drug handling error (100%). We found a significantly higher amount of complete drug prescriptions with one of the implemented measurements e-prescribing, medication reconciliation and clinical pharmacists (Fisher's exact test two tailed, each p<0.001; CI 95%). Drug administration errors and drug handling errors were not significantly improved. Among the most frequently involved drug were drugs for acid-related disorders, immunosuppressant, and antineoplastic drugs. *Conclusions:* In the nearly 1,000 prescriptions and drugs analyzed, medication errors were still common. Various preventive strategies had been implemented in recent years, positively influencing the predefined errors rates.

1. Introduction

Medication errors affect the efficacy of pharmacotherapies (Wittich et al. 2014). They can result in clinical consequences for the patient in terms of adverse effects (Mejía et al. 2020). Such errors can occur anytime from the moment of a drug prescription to its administration (Suclupe et al. 2020). Medication errors are preventable through appropriate strategies (Bertsche et al. 2010a). In recent years, numerous strategies have been implemented to prevent clinical consequences for the patient due to such errors (Khalil et al. 2017). Examples of such preventive strategies are the introduction of e-prescribing (Ciapponi et al. 2021), the deployment of clinical pharmacists on wards (Ensing et al. 2015) and medication reconciliation during elective patient's admission (Abdulghani et al. 2018).

In this present study, we performed a comprehensive investigation in ten different wards of a university hospital where in part e-prescribing, clinical pharmacists and medication reconciliation have been implemented. We aimed to identify error rates depending on the wards and implemented preventing strategies. For this purpose we assessed predefined prescription, administration, and drug handling errors. Prescriptions errors contain the quality of drug prescriptions by physicians on wards. Administration errors contain the accuracy of dispensed drugs by nurses on wards. Drug handling errors contain the correct handling of sensitive drugs (light- and moisture sensitive drugs, indivisible drugs, drugs, which ought to be taken on an empty stomach).

2. Investigations and results

2.1. Setting

We performed a comprehensive analysis to evaluate drug prescriptions, administration and handling in a university hospital setting. For this purpose, we examined medication errors occurring on the following wards: neurology, cardiology, radiotherapy, gastroenterology/hepatology, neurosurgery, ophthalmology, gynecology, palliative care, pediatrics and surgical intensive care unit (surgical ICU).

An interdisciplinary expert panel consisted of representatives of the University Hospital Pharmacy, the Department of Clinical Pharmacy, as well as nursing service managers and other nursing staff. On demand, medical and IT expertise was also called in. The interdisciplinary expert panel selected the participating wards and predefined medication errors to be observed. To ensure a representative picture and at the same time good feasibility within the available resources, the following steps have been carried out for selection of participating wards.

1. We first randomly selected a broad range of wards from our university hospital. The selection criteria were defined by the expert panel as follows:
   (a) A balanced selection of both, internal medicine and surgical disciplines.
   (b) Disciplines in terms of special drug processes, e.g. intensive care medicine and ophthalmology, should also be included.
   (c) Wards where strategies had been introduced in recent years, e.g. an electronic prescription platform, a pharmacist on the ward and a pharmaceutical medication reconciliation should also be included. However, a selection of wards without these strategies should also be explicitly included.
2. From all these criteria, the expert panel selected ten wards that were invited to participate.
3. All wards approached participated voluntarily.

All of the ten wards, except the surgical ICU, used paper-based medication charts for drug prescriptions by physicians. Physicians on surgical ICU used e-prescribing since 2003. For e-prescribing a computerized physician order entry (CPOE), but no clinical decision support system (CDSS) was used on surgical ICU. Clinical pharmacists were on duty on surgical ICU since 2009 and neurosurgery since 2017 once a week. Clinical pharmacists checked prescribed drugs of in-patients for drug-drug interactions and changed patients' medications of newly admitted patients to in-house drugs.

On ophthalmology, a medication reconciliation was performed during elective patient's admission since the beginning of 2019. Medication reconciliation comprises drug-drug interaction checks and changing patients' medications to in-house drugs by creating standardized medication lists for hospitalization on ophthalmology. The other participating wards did not have implemented preventing strategies on ward, but were taken care of as part of routine care. Clinical pharmacists were available for inquiries, for example about drug information.

Preparation of drugs took place during night shift for drug administration on the following day (neurology, cardiology, radiotherapy, gastroenterology/hepatology, neurosurgery, ophthalmology and gynecology) or on the same day right before administration (palliative care, pediatrics, surgical ICU). Depending on the time of drug preparation and drug administration, prepared drugs are stored in drug dosettes on ward up to 24 hours.

2.2. Ethics and data protection

The study was performed as part of a quality assurance study. All data were collected anonymously without patient reference and an ethics vote or written informed consent was therefore not required in accordance with the applicable state hospital law.

2.3. Study protocol

Before we began, the nursing managers of respective wards were informed about the intended study. Two pretests were performed in a hospital ward that was not enrolled in the study. The assessment took place on 26 weekdays in June and July 2019. The ten wards were visited on three days in three blocks. Within these blocks, the assessment days were randomized. The expert panel predefined medication errors in three categories (Table 2): prescription errors, administration errors, and drug handling errors.

Medication errors were predefined by the expert panel based on data from literature (Barker et al. 2002, Bertsche et al. 2008, Rodriguez-Gonzalez et al. 2011) and the internal guideline for drug administration using the rule of the five rights: the right patient, right drug, right dose, right route and right time. In addition, the administration of medication was evaluated with regard to light protection in accordance with internal guidelines. Internal guidelines for drug administration also state, that drugs requiring light protection ought to be prepared outside blister packs only immediately before drug administration. The physical susceptibility of moisture-sensitive drugs was also taken into account. Due to the physical susceptibility of moisture-sensitive drugs, we extended this specification to the corresponding drugs.

2.4. Monitoring and identification of medication processes

A pharmacy master student documented drug prescriptions of consecutive patients of the participating wards by reviewing paper-based medication charts, medication lists of the medication reconciliation or e- prescriptions in the CPOE. She assessed the drugs prepared for administration in the hospital wards using a list of the in-house brands and the IDENTA® search in the GELBE LISTE®. Additionally, she documented how the drugs were stored (e.g. in regard to light and moisture protection) on the ward. Afterward, the collected data were evaluated to identify predefined medication errors. An experienced pharmacist re-checked the collected data and the assessment for accuracy. This procedure was pre-tested twice for its performance and feasibility. Only solid peroral drug forms were included as they could be identified afterward without attending the routine process of drug preparation for administration. Inspections included any drug prescription with all associated information and any completed action of drug preparation for following drug administration. Drug handling included the assessment of protected storage concerning photo- and moisture-sensitivity, no splitting of indivisible tablets, and separate storage of drugs, which ought to be taken on an empty stomach.

2.5. Classification of drug-related problems

An expert panel of two pharmacists with 6 and 25 years of clinical experience categorized medication errors into drug-related problems (DRP) in accordance to the study of Wildhagen et al. (2023) and to the classification of the Agency for Healthcare Research and Quality (AHRQ).

According to Wildhagen et al. (2023), medication errors were categorized into DRP Level-I: Problematic routine procedures that have not yet resulted in a medication error, DRP Level-II: Problematic routine procedures where medication errors have occurred but have not yet reached the patient or DRP Level-III: Problematic routine procedures where medication errors have occurred and have reached the patient.

According to the Classification of medication errors of the AHRQ, medication errors were assigned to the following categories:

A No error, capacity to cause error; B Error that did not reach the patient; C Error that reached patient but unlikely to cause harm (omissions considered to reach patient);

D Error that reached the patient and could have necessitated monitoring and/or intervention to preclude harm; E Error that could have caused temporary harm;

F Error that could have caused temporary harm requiring initial or prolonged hospitalization; G Error that could have resulted in permanent harm; H Error that could have necessitated intervention to sustain life; I Error that could have resulted in death.

2.6. Statistical methods

Statistical analysis was performed by using Microsoft Excel 2016 (version 16.0, Microsoft Corporation, Redmond, WA, USA) and SPSS (version 24, IBM Corporation, Armonk, NY, USA). In accordance to group sizes the two-tailored Fisher's Exact test was used, to evaluate the significant differences in number of observed medication errors. A p-value ≤ 0.05 was considered to indicate significance.

2.7. Identified medication errors

We analyzed predefined medication errors for 959 prescriptions with 933 drugs for 182 patients (6-26 patients per ward, 98 females) during the study period. The median age of patients was 66.5 years (Quartile range 25% (Q25)-Quartile range 75% (Q75): 56-78 years), and the median number of drugs per patient was 5 (Q25-Q75: 3-7). Table 1 displays the identified predefined medication errors of the

Table 1: Types of identified medication errors

	Number of observed steps in the medication process	Number of observed medication errors	Error rate in percent [%]	Examples
Drug prescription errors (DRP Level/AHRQ Classification)				
Missing information on drug form (II.b./B)	959*	874	91.1%	No information about drug form, e,g., melperone 25mg 0-0-0-1, lamotrigine 100mg 1-0-1-0, pregabalin 100mg 1-1-1-0
Missing information on dose strength (II.c./B)	959	48	5.0%	No information about drug dose, e.g., Ferrous Glycine Sulfate (Ferrosanol®) p.o. 1-0-1, calcium carbonate effervescent tablet 1-0-1
Missing information on strength unit (II.c./B)	959	134	14.0%	No information about strength unit, e.g., tamoxifen 20mg 0-1-0
Missing information on dosage regimen	959	18	1.9%	No information about dosing regimen, e.g., clarithromycin 2x500mg p.o. Sulfamethoxazole /Trimethoprim (Cotrim ®) 2x960mg
Obsolete data – Extra dose/missing dose (I.f./A)	959	4	0.4%	According to consultation between physician and nursing staff, proceeding of drug therapy, despite paused prescription, e.g., metformin 500mg tablets or apixaban 5mg tablets and no preparation of drug, because it should only get dispensed for evening application, e.g. melperone 12.5mg 1-1-2
Obsolete data – Wrong/different drug (I.f./A)	959	5	0.5%	According to consultation between physician and nursing staff preparing of unprescribed substance, despite different prescription, e.g., preparation of enalapril 5mg instead of prescribed lisinopril 5mg, ondansetron 4mg instead of granisetron 2mg
Drug administration errors *(DRP Level/AHRQ Category)*				
Omission of drug (III.a./C-I[a])	959	3	0.3%	Missing drug, e.g., pantoprazole 40mg, simvastatin 20mg, acetylsalicylic acid 100mg
Substance was not in accordance with the prescription (III.c./C-I)	933**	1	0.1%	Prescribed drug levodopa/carbidopa (Isicom®) 100mg/25mg, prepared drug levodopa/benserazide (Madopar T®) 125mg
Drug form was not in accordance with the prescription (II.b./B)	85***	4	4.7%	Preparation of other than prescribed drug form, e.g., prescribed loperamide 2mg tablets, prepared loperamide 2mg capsules; prescribed valproic acid (Orfiril long ®) 500mg sachet with retard minitablets, prepared for administration valproic acid (Valproate Hexal chrono®) 500mg retard tablet
Release dose formulation was not in accordance with the prescription (II.b./B)	22	16	72.7%	Preparation of tramadol retard tablet, instead of tramadol tablet prescription, preparation of oxycodon 10mg retard tablet, instead of oxycodon 10mg tablet prescription
Dose was not in accordance with the prescription (III.d./C-I)	886	5	0.6%	Preparing of wrong single doses/omission of single doses, omission of one capsule tacrolimus (Prograf® 0,5mg) for the evening, preparing propranolol 40mg, instead of propranolol 25mg prescription
Dosage regimen was not in accordance with the prescription (III.d./C-I)	918	6	0.7%	Preparing for another daytime than prescribed, e.g., haloperidol 1mg tablet dispensed for intake in the evening instead prescription for intake at night, pantoprazol dispensed for morning intake, instead prescription for intake in the evening
Drug handling errors *(DRP Level/AHRQ Category)*				
Photosensitivity was not considered (n.a.[b]/C-I)	49 ****	49	100.0%	Storage outside blister pack of photosensitive drugs, e.g., amlodipine (21), metoprolol (20), lercanidipine (3), thiamazole (3), furosemide (1), zuclopenthixol (1)
Moisture-sensitivity was not considered (n.a./C-I)	137	122	89.1%	Storage outside blister pack of moisture-sensitive drugs, e.g., acetylicsalicylic acid (21), levodopa/benserazide (11), calcium carbonate/colecalciferol (10), tilidine/naloxone (10), folic acid (9)
Indivisible drugs were splitted (n.a./C-I)	394	6	1.5%	Splitting of tablets, even though drugs must not be split according manufacturer's information, e.g., ondansetron (2) levothyroxine/ potassium iodide (1), sulthiame (1), doxazosin (1), haloperidol(1)
Missing separation of drugs, which ought to be taken on an empty stomach (n.a./C-I)	141	129	91.5%	Storage in the same compartment with other drugs, even though drug should be taken on a fasting stomach, e.g., pantoprazole (72), levothyroxine (33), iron (7), tacrolimus (4), levodopa/ benserazide (4)

Abbreviations: DRP – drug-related problem(s); AHRQ – Agency for Healthcare Research and Quality; n.a – not accessible.
* Number of included drug prescriptions
** Number of dispensed drugs
*** Number of dispensed drugs based on drug prescriptions, which contained respective information; e.g., only in 85 dispensed drugs correctness of drug form were evaluated, because only 85 prescriptions contained information about the intended drug form
**** Number of drugs with special drug handling, e.g., 49 of dispensed drugs were photosensitive, evaluation, if these 49 drugs were dispensed with light protection
[a] The categories with actual patient events could not occur in our study since, in the case of an error being identified, timely intervention was made to prevent such events (also for ethical reasons). Therefore, only classifications A, B, C-I were assigned in this context. Errors, that would have reached the patients were assigned C-I, because we did not observe resulting harm of the patient in this study.
[b] DRP-levels were not accessible, because Wildhagen et al. 2023 did not include categorization of drug handling errors
Classification of medication errors A-I according to AHRQ: see section 2.5

Table 2: Medication errors by drug classes accordig to ATC codes

Drug class	Total number of drug prescriptions	Drug prescription errors	Drug administration errors	Drug handling errors	Number of errors (total)	Number of errors per drug (95% CI)
Antihypertensives/cardiac drugs	**305**	319	6	63	**388**	1.27 (1.20 – 1.34)
Vitamins/minerals/enzymes	**95**	164	8	48	**220**	2.32 (2.08 – 2.55)
Drugs for acid-related disorders	**82**	87	4	73	**164**	2.00 (1.87 – 2.13)
Thyroid hormones/ sexual hormones/ corticoidsteroids	**67**	68	-	41	**109**	1.63 (1.47 – 1.79)
Anticonvulsants/anti-Parkinsons drugs	**64**	64	2	26	**92**	1.44 (1.23 – 1.65)
Antidiabetics/anti-hyperlipidemic drugs/uricostatics	**85**	89	1	-	**90**	1.06 (0.97 1.15)
Psycholeptic drugs/ psychoanaleptics	**69**	74	3	11	**88**	1.28 (1.14 – 1.41)
Anticoagulants	**47**	49	1	22	**72**	1.53 (1.34 – 1.73)
Opioid analgesics	**35**	38	6	10	**54**	1.54 (1.34 – 1.75)
Laxans/antiemetika/ antidiarrhoika	**28**	42	1	2	**45**	1.61 (1.35 – 1.86)
Non-opioid analgesics/ antirheumatics	**28**	29	1	-	**30**	1.07 (0.93 – 1.21)
Immunosupressants/antineoplastic drugs	**15**	20	1	8	**29**	1.93 (1.49 – 2.38)
Urologicals/other drugs	**25**	25	1	2	**28**	1.12 (0.86 – 1.38)
Antibiotics/antiinfectives	**14**	15	-	-	**15**	1.07 (0.82 – 1.32)
Total	**959**	**1083**	**35**	**306**	**1424**	**1.48 (1.43 – 1.53)**

three categories drug prescription errors, drug administration errors and drug handling errors. Drug prescription errors and drug administration errors are evaluated in relation to the number of steps in the medication process in which these errors were possible. Drug handling errors are evaluated in relation to the total amount of drugs for which the examination aspect was relevant.

Regarding drug prescriptions, "missing information on drug form" proved to be the most common error (91.1%; 874/959). Following was "missing information on dose strength" (5.0%; 48/959) and "missing information on dosage regimen" (1.9%; 18/959).

94.5% (906/959) of observed drug prescriptions were incomplete regarding dose strength, strength unit, drug form and dosage regimen.

At drug administration, the release dose formulation was not considered appropriate in 72.7% (16/22), and an "drug form was not in accordance with the prescription" was found in 4.7% (4/85), while the wrong dose was identified in 0.6% (5/886).

Regarding drug handling, "photosensitivity" was not appropriately considered in 100% (49/49). In 91.5% (129/141) of observed drugs, "separation of drugs" which ought to be taken on an empty stomach" from others, was not considered correctly. In 89.1% (122/137), the moisture-sensitive properties of drugs were not considered appropriately.

2.8. *Impact of implemented strategies*

18 of 959 (1.9%) drug prescriptions and 18 of 933 (1.9%) drugs were observed on ward with implemented e-prescribing. 141 of 959 (14,7%) drug prescriptions and 138 of 933 (14.8%) drugs were observed on wards with implemented clinical pharmacists and 106 of 959 (11.1%) drug prescriptions and 97 of 933 (10.4%) drugs were observed on ward with implemented medication reconciliation. In total 17 of 18 (94.4%) prescriptions were complete with e-prescribing implemented. 19 of the observed 141 (13.5%) drug prescriptions with implemented clinical pharmacist were complete and 31 of 106 (29.2%) drug prescriptions with implemented medication reconciliation were complete. Significantly less drug prescription errors appeared with implemented e-prescribing (Fisher's exact test two tailed; $p<0.001$, CI 95%), clinical pharmacists (Fisher's exact test two tailed, $p<0.001$; CI 95%) or medication reconciliation (Fisher's exact test two tailed; $p<0.001$, CI 95%) compared to prescriptions on wards without implemented preventing strategies. In total 5 of 712 (0.7%) observed prescriptions were complete on wards without any preventing strategies (i.e. neurology, cardiology, radiotherapy, gastroenterology/hepatology, gynecology, palliative care, pediatrics).

We did not observe an occurrence of significantly less drug administration errors on wards with implemented e-prescribing (Fisher's exact test two tailed; $p=0.136$, CI 95%), or implemented medication reconciliation (Fisher's exact test two tailed; $p=1.000$, CI 95%). Significantly more drug administration errors were observed at wards with implemented clinical pharmacists (Fisher's exact test two tailed, $p=0.024$; CI 95%).

There was no significant difference of occurrence of drug handling errors between wards with and without implemented e-prescribing (Fisher's exact test two tailed $p=0.386$, CI 95%), clinical pharmacists (Fisher's exact test two tailed; $p=0.708$, CI 95%) or medication reconciliation (Fisher's exact test two tailed; $p=0.878$, CI 95%).

2.9. *Drug classes affected by medication errors*

Table 2 provides an overview of the drug classes involved in the error categories. The most frequent drug classes involved and medication errors per drug were vitamins, minerals and enzymes: 2.32 (95% CI, 2.08 – 2.55), drugs for acid-related disorders: 2.00 (95% CI, 1.87 – 2.13), and immunosuppressants/antineoplastic drugs: 1.93 (95% CI, 1.49 – 2.38).

3. Discussion

3.1. *Considerations on the main findings*

Surprisingly, our comprehensive study of medication errors in nearly 1,000 analyzed drug prescriptions and observation of dispensed drugs for administration in the entire medication process, from drug prescribing to drug handling in ten participating wards, painted a very heterogeneous picture. In prescribing as well as in preparing for drug administration and handling drugs, the error rates were unexpectedly high in some error categories but low in others. Recently implemented preventing strategies, such as e-prescribing, clinical pharmacists and medication reconciliation, have had a significant impact on improving the completeness of drug prescriptions. Still, low rates of complete drug prescriptions on wards without implemented e-prescribing were particularly striking given that this is the very start of the medication process in the hospital. Frequently, when information was missing, the prescription was unclear in terms of the information in question, which should be considered unacceptable with regard to medication safety. Drug administration errors showed a high incidence of preparing an incorrect release dose formulation for drug administration, but much lower rates for omission, incorrect substance, incorrect drug form, dose and dosage regimen. Our study did show significantly higher error rates of drug administration errors on wards with implemented clinical pharmacists. Clinical pharmacists were implemented on surgical ICU and neurosurgery. Implementation of ward pharmacists may have been focused on wards with high error potential. Furthermore staff on ICU, but also surgical wards, such as neurosurgery may have less experience with administration of solid peroral drugs. The largest part of prescribed drugs on these wards are liquid drugs for intravenous administration. Therefore, we do not believe that the higher error rates were caused by the implementation of clinical pharmacists on ward.

Drug handling appeared problematic in the clinical medication process. All photo- and a high amount of moisture-sensitive drugs were prepared without protection. Photo- and moisture-sensitive drugs were stored without any protection up to 24 hours, depending on the time period between preparation for drug administration and the actual drug administration. This may lead to drug instabilities and has capacity to cause medication errors/patient harm. Our statistical evaluation did not show significant lower error rates of drug handling errors on wards with implemented e-prescribing, clinical pharmacist or medication reconciliation.

We identified a wide range of drug classes affected by medication errors. Only errors in separating drugs, which ought to be taken on an empty stomach or for photo- or moisture sensitivity were due to substance-type properties. Irrespective of the drug classes, an accumulation of errors was also frequently observed, with more than one error documented on average. Many drugs with narrow therapeutic ranges or other critical properties, for example hormones, anticonvulsants, psycholeptics, psycho analeptics and immunosupressants were also affected, leading to likely clinical consequences for many of the identified medication errors.

3.2. Comparison of error rates to former study results

Studies conducted 18 to 21 years ago reported medication error rates in drug prescriptions up to 23.5% and 39.0%. (Fijn et al. 2002; Lisby et al. 2005). We assessed a much higher error rate of 94.5% (906/959) in nearly 1,000 drug prescriptions, even though several former studies assessed additional parameters such as correct or complete patient data, treatment time and documentation of the prescription date and presence of physicians' signature. Similar to this study, former results highlighted missing information on the drug form as the most common error (Lisby et al. 2005). Further observed error rates for missing dosage regimen with 1.9% (18/959) in our study compared to 1.4% (27/1913) – 4.2% (18/433) and for missing dose strength with 5.0% (48/959) in our study compared to 2.1% (41/1913)-6.9% (30/433) fit into the range of error rates in drug prescription reported in earlier literature (Lisby et al. 2005; Fijn et al 2002).

Overall, no changes are visible in the error rates of drug administration over the past years, as our results of 3.8% (35/933) errors in drug administration are quite consistent with previous findings from 1995 of 3.5%, 2005 of 4.0% and 2015 of 3.3% (Lisby et al. 2005; Ridge et al. 1995; Cottney and Innes 2015).

While drug omission was the most frequent error in the previous studies, the results showed that wrong release dose formulation occurred most frequently (72.7%) in this study. In comparison, omission occurred relatively rarely (0.3%). Former studies did not evaluate stringently the correctness of release dose formulation in the clinical medication process as we did.

So far, only a few studies have thematized minor aspects of drug handling errors. Gerber et al. (2008) observed wrong tablet splitting as the most common medication error. Rodriguez-Gonzalez et al. (2011) recognized drug intake of 321 (13.9%) drugs, which ought to be taken on an empty stomach, together with other drugs. Berdot et al. (2012) identified 10 errors (25.0%) in taking thyroid hormones together with sustenance. Division of indivisible tablets represented the least common drug-handling error in our study. In contrast, lack of moisture protection and failure to separate drugs, which ought to be taken on an empty stomach showed high error rates of 89.1% and 91.5%, respectively. Light protection was not applied to 100.0% of relevant drugs.

3.3. Comparison of impact of preventing strategies to former studies

Former studies also observed significant reduction of prescription errors. Hernandez et al. (2015) and Colpaert et al. (2006) also observed significantly less prescription errors after implementing e-prescribing. Hernandez et al. (2015) conducted a study on an orthopedic surgery ward and most common errors of missing information about dose and drug form no longer occurred after implementation of e-prescribing. As in our study, Hernandez et al. (2015) did not observe a significant reduction of administration errors. Bond et al. (2002) showed with a simple regression model of collected data from 1081 United States hospitals occurrence of significantly less medication errors with clinical pharmacists participating on medication reconciliation during patient admission provided by pharmacists. Ciapponi et al. (2021) state in their review of three randomized control trials, that implementation of medication reconciliation may reduce occurrence of medication errors in the clinical setting.

3.4. Outlook and consequences of the study results

Implemented preventing strategies of e-prescribing, clinical pharmacists and medication reconciliation succeeded in a significant reduction of prescription errors. More time-intensive preventing strategies, such as e-prescribing or clinical pharmacists show also significant error reduction, as do easier to realize strategies such as implementation of medication reconciliation. We did not show a significant effect on drug handling errors. At drug administration implementation of e-prescribing and medication reconciliation did not show significant error reduction. We found significantly lower drug prescribing error rates on wards with clinical pharmacists than without. In contrast, drug administration error rates appeared to be higher on wards where clinical pharmacists were implemented. It should be noted that clinical pharmacists are indeed particularly well accepted on wards where the risk of drug-related problems is particularly high. Although these wards are obviously particularly susceptible to administration errors and open to pharmaceutical interventions, the results show that the measures taken by clinical pharmacists in the area of administration have hardly been effective to date. Additional intervention concepts, such as pharmaceutical training for newly recruited and rotating nursing staff (Celebi et al. 2009), therefore appear to be necessary in order to achieve lower error rates in the area of medication administration in the near future. Thereby that e-prescribing and clinical pharmacists on ward were both implemented on surgical ICU we cannot clearly state, which of the error reducing measures has led (mostly) to error reduction. Additive positive effects by implementation of both measurements can be assumed, but need to be investigated by further studies. On the level of drug prescription, tools for e-prescribing have been implemented in recent years in some hospitals (Bertsche et al. 2010b). At our university hospital, e-prescribing was implemented in intensive care units only. However, our study shows that e-prescribing causes a significant effect of prescription error prevention. Many studies indeed reported an improvement in the error rates – but mainly in a transient manner directly after implementing such strategies. However, a longer-term view is usually less positive. Clinical pharmacists on wards, for instance, often only achieve long-lasting positive effects if they are involved regularly several times a week. In conclusion, all these strategies should be designed to be sustainable and comprehensive to be successful in the long term.

3.4. Limitations

Medication errors were evaluated on several wards at just one hospital facility, so the transferability of our results to other hospital facilities is only possible to a limited extent. Despite high number of analyzed drug prescriptions and observed drugs, the numbers for statistical investigation were still small. Out of the inpatient medication process, only prescribing, preparing for administration and handling drugs were selected for observation as these steps were identified as prone to errors (Bertsche et al. 2008). Solely solid peroral drugs were included in this study.

3.5. Conclusion

The error rates differ considerably in the predefined error types of drug prescription errors, administration errors and drug handling errors. Missing drug forms at drug prescriptions, incorrect release dose formulations at drug administration, and failure to consider substance properties such as photo- and moisture sensitivity at drug handling were particularly frequent error-prone processes. We found a significant correlation between the implementation of preventing strategies such as e-prescribing, clinical pharmacists and medication reconciliation and error reduction in drug prescribing. A wide range of drugs were affected by medication errors.

Conflicts of interest: None declared.

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