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Medication Errors Caused by Nurses and Physicians in a Swiss Acute Care Community Hospital: Frequency and Correlation to Nurses' Reported Workload

Von Pflegefachpersonen und Ärzten/-innen verursachte Medikamentenfehler in einem Schweizer Akutspital: Häufigkeit und Korrelation zur Arbeitsbelastung von Pflegefachpersonen

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Abstract

Objectives: This study was carried out in a Swiss acute care community hospital to investigate the frequency, type, causes and potential clinical consequences of medication errors (MEs) caused by nurses and physicians in all stages of a technology-supported medication process, the relationship between the nurses' workload and the medication administration errors (MAEs) and their reason for workload.
Methods: In this descriptive cross-sectional study, a questionnaire, the adapted Medication Error Self Reporting Tool (A-MESRT), was used to identify MEs in all stages of the medication process and record nurses' self-perceived workload during medication administration.
Results: A total of 1936 completed A-MESRTs were returned. A total of 751 (38.8%) respondents reported different MEs. The highest number of errors occurred during medication administration (43%), followed by errors during dispensing (34%) and physician ordering errors using a computerised physician order entry (CPOE) system (23%). Of the 768 (100%) handwritten orders, 232 (30.2%) were erroneous. Moreover, the greater the individual nurse's workload during a shift, the higher was the relative probability of committing an MAE ($\chi^2 = 85.479$, df = 1, OR = 2.129, $p < 0.001$). Furthermore, the three main causes of high or very high workload were revealed: (1) many newly operated patients to monitor; (2) complex multimorbid patients, for example, those with delirium; and (3) patients with complications after surgery.
Conclusion: The A-MESRT showed that the highest rate of MEs caused by nurses and physicians is in the non-technologically supported steps, demonstrating the potential benefits of a technology-supported medication process. Moreover, this study revealed a statistically significant correlation between nurses' workload and MAEs.

Abstract

Ziel: Diese Studie wurde in einem Schweizer Akutspital durchgeführt, um die Häufigkeiten, die Art, die Ursachen und die potenziellen klinischen Konsequenzen von Medikamentenfehlern (MEs), die von Pflegefachpersonen und Ärzten in allen Stufen eines technologisch unterstützten Medikationsprozesses verursacht wurden, zu untersuchen. Des Weiteren wurden die Ursachen sowie ein möglicher Zusammenhang zwischen der Arbeitsbelastung von Pflegefachpersonen und der Häufigkeit von Medikamentenverabreichungsfehlern überprüft.
Methode: In dieser deskriptiven Querschnittstudie wurde ein adaptierter Fragebogen (A-MESRT) verwendet, um MEs in allen Stufen des Medikamentenprozesses zu identifizieren sowie die individuell wahrgenommene Arbeitsbelastung von Pflegefachpersonen bei der Medikamentenverabreichung zu erfassen.
Ergebnis: Insgesamt wurden 1936 A-MESRTs zurückgegeben. Dabei wurden 751 (38,8%) verschiedene Medikationsfehler rapportiert. Bei der Medikamentenverabreichung (43%) traten die meisten MEs auf, gefolgt von MEs beim Richten (34%) sowie MEs bei der elektronischen ärztlichen Verordnung (23%). Von den 768 (100%) handgeschriebenen ärztlichen Verordnungen waren 232 (30,2%) fehlerhaft. Die Daten zeigen, umso höher die Arbeitsbelastung von Pflegefachpersonen war, desto höher wurde die relative Wahrscheinlichkeit, einen Fehler bei der Medikamentenverabreichung zu machen ($\chi^2 = 85,479$, df = 1, OR = 2,129, $p < 0,001$). Zudem wurden die drei Hauptgründe für eine hohe oder sehr hohe Arbeitsbelastung aufgedeckt: (1) viele zu überwachende frisch operierte Patienten; (2) komplexe multimorbide Patienten, wie solche in einem Delirium; oder (3) Patienten, welche nach einer Operation Komplikationen hatten.
Schlussfolgerung: Die vorliegende Studie konnte mit dem A-MESRT aufzeigen, dass die meisten MEs, die durch Pflegefachpersonen und Ärzte verursacht wurden, in den nicht technologisch unterstützten Stadien auftraten. Dies zeigt die Stärke eines technologisch unterstützten Medikationsprozesses. Darüber hinaus konnte ein statistisch signifikanter Zusammenhang zwischen der Arbeitsbelastung von Pflegefachpersonen und der Häufigkeit von Medikamentenverabreichungsfehlern aufgezeigt werden.
Schlüsselwörter: Medikamentenfehler; Unerwünschte Arzneimittelwirkungen; Computergestützte ärztliche Verordnungen CPOE; Arbeitsbelastung

Keywords
Medication Errors – Drug-Related Side Effects and Adverse Reactions – Medication Systems – Medical Order Entry Systems – Workload – Self-Report

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INTRODUCTION

Since the landmark report "To Err Is Human" was published by the National Academy of Medicine (NAM) in 2000, healthcare institutions and professionals have increased their focus on the prevention of medical errors (Aspden, Wolcott, Bootman & Cronenwett, 2006; Kohn, Corrigan & Donaldson, 2000). More than half of the medical errors made are medication errors (MEs), and MEs are responsible for the most common adverse medical events in acute care settings (Aspden et al., 2006; Bates, Boyle, Vander Vliet, Schneider & Leape, 1995; Landrigan et al., 2010). The prevalence of MEs varies between 2% and 75%, depending primarily on the study's methodology (Lisby, Nielsen, Brock, & Mainz, 2010). The consequences of MEs for patients range from no harm to permanent injury or even death (Aspden et al., 2006; Kohn et al., 2000). In the United States, approximately 7,000 patients die each year as a result of MEs (Kohn et al., 2000). An adverse drug event is usually defined as harm caused by the use of a medication (Nebeker, Barach & Samore, 2004). Previous studies indicated that approximately 1% of MEs result in an adverse drug event (Bates et al., 1995; Kaushal et al., 2001). Up to two-thirds of adverse drug events are error associated, preventable and caused primarily by nurses and physicians (Levinson & General, 2010).

According to the definition by the National Coordination Council for Medication Error Reporting and Prevention (NCCMERP, 2017), MEs are caused by various healthcare professionals and can occur during all stages of the medication process, such as ordering, transcribing, dispensing, administration and monitoring (Brady, Malone & Fleming, 2009). One large-scale study analysing MEs in a non-technologically supported medication process found that 39% of errors were committed during handwritten ordering, 38% during medication administration, 12% during order transcription and 11% during medication dispensing (Leape et al., 1995). Barker, Flynn, Pepper, Bates and Mikeal (2002) reported that every fifth dose of non-technologically supported medication administered was associated with an error, including the wrong time of administration (43%), omission of a dose (30%), wrong dosage (17%) and other errors (10%).

There is a strong need to increase safety during the entire medication process, and the use of new technology systems for healthcare professionals is pivotal (Landrigan et al., 2010). New systems such as computerised physician order entry (CPOE), barcoded medication preparation and administration (BCMA), automated dispensing devices (ADDs) and the electronic medication administration record (eMAR) enable healthcare professionals to provide safer and more efficient quality of care with regard to the prevention of MEs (Bates, 2000; Poon et al., 2010; Shulman, Singer, Goldstone & Bellingan, 2005). Comparison of a CPOE system with handwritten prescriptions by physicians, for instance, showed a significant decrease in MEs (Shulman et al., 2005). Bates et al. (1998) found up to a 55% reduction in serious MEs when physicians used a CPOE system. Poon et al. (2010) significantly reduced ME rates by 40% in an academic medical centre by using CPOE, BCMA and eMAR systems. Additionally, there were reductions of 40% for non-timing medication administration errors (MAEs) and 50% for potential adverse drug events. Therefore, technology-supported systems have become increasingly common in recent decades and their implementation seems to be highly beneficial for healthcare professionals.

However, most medical errors committed by healthcare professionals are multifactorial and are related to human factors, including cognitive, skill-set, task-based and personal impairments (Cosby, 2003). Task-based errors include errors in routine behaviours that are required for safe and effective patient care and, generally, reflect high workload, inattentiveness owing to distraction or fatigue or teamwork failure (Cosby, 2003; Valentine et al., 2009). High workload of health professionals can be thought of as the ratio of demands to available resources at different levels, for example, unit, job and task (Holden et al., 2011). The jobs of nurses and physicians are considered to be demanding and stressful, and multiple factors can affect both their mental and emotional condition and their professional performance and, therefore, ultimately have an impact on patient safety (Pelliciotti & Kimura, 2010). One-third of the physicians in Switzerland experience stress at work, which has negative impacts on their health, their satisfaction with life and the outcomes of their patients (Williams, Manwell, Konrad & Linzer, 2007).

Nursing staff shortages, high workload and working overtime are common causes of MEs – especially MAEs (Eslamian, Taheri, Bahrami & Mojdeh, 2011). The prevalence of MAEs in healthcare settings is still high, and studies have shown that nurses' workload seems to be an important contributor to MAEs by reason of factors

such as multitasking and inadequate attention (Eslamian et al., 2011; Kohn et al., 2000). Data from 12 European countries and the United States showed that nurses in hospitals with higher patient-to-nurse ratios had higher workloads, but the correlation to MAEs was not clear (Aiken et al., 2012). As nurses are the last link in the medication process, the occurrence of MAEs needs to be investigated from the nurses' point of view (Keers, Williams, Cooke & Ashcroft, 2013a).

In Switzerland, up to 7.5% of patients experience at least one adverse drug event during their hospital stay (Hardmeier et al., 2004). Currently no data on MEs caused by nurses and physicians at every stage in a technology-supported medication process, taking into account nurses' reported workload, are published. To close this gap, this study adapted an existing ME reporting method including nurses' workload.

The primary aims of this study were (1) to assess the frequency, type, causes and potential clinical consequences of MEs caused by nurses and physicians and (2) to explore correlations between nurses' reported workload and the frequency of MAEs.

METHODS

Design

In order to achieve the aims of the study, an observational design with repeated measures using an anonymous incident reporting tool over time was used.

Setting and sample

The study was conducted in a 267-bed acute care community hospital in a small city in the State of Berne, Switzerland, from 1 October to 31 November 2013. The acute care community hospital is responsible for more than 130,000 people in the region. All six wards of the surgical department, comprising 122 beds, participated. The wards covered six different surgical disciplines: orthopaedics, visceral and spinal surgery, urology, gynaecology and otorhinolaryngology.

A convenience sample of registered nurses (RNs) was recruited at two information events about the purpose of the study. All RNs (n = 110) working on the units during the data collection period were eligible to participate in the study. The inclusion criterion was the involvement in the medication process and in the direct patient care.

Variables

The outcome variables of interest were frequency and type of MEs caused by nurses and physicians, the consequences of MEs for patients and the causes of nurses' reported high workload. Furthermore, nurses' reported workload was used as the predictive variable of interest to compute correlations with MAEs.

Measurements

For this study, a novel adaptation of the Medication Error Self Reporting Tool (MESRT) was developed. The MESRT, established and validated by Küng et al. (2013), includes 13 items with a scale content validity index (CVI) of 0.93. This tool records the frequency and type of MAEs and prescription errors, as well as the number of MEs prevented by RNs and the consequences of MEs for patients, and was used in the non-technology-supported medication process of a tertiary teaching hospital. The adaptation of the Medication Error Self Reporting Tool (A-MESRT) developed for this study encompasses 25 multiple-choice items and was supported by the original author. Compared to the original tool, the A-MESRT in this study covers all stages of the medication process and is based on the definition of MEs in Table 1. The A-MESRT records the frequency, the type of medication prescribed, the MAEs, the consequences of MEs for patients, the nurses' workload and the causes of high or very high workload. The nurses' individual perceived workload was generalised including the ratio of demands to available resources (Keers, Williams, Cooke & Ashcroft, 2013b). Therefore, a five-point Likert scale was used: 1 = no workload, 2 = low workload, 3 = medium workload, 4 = high workload and 5 = very high workload (see table 4 in Appendix).

Content validity testing

One month before the onset of the study, the A-MESRT was evaluated for its content validity with a randomly selected focus group of two representative RNs from each ward (n = 12 RNs). The CVI – a method used to quantify content validity of multi-item scales – was calculated according to Polit et al. (2007). A CVI can be computed for each item (I-CVI) on a given scale as well as for the entire scale (S-CVI). To enable calculation of the I-CVI, all participating RNs were asked to rate the relevance of each A-MESRT item on a four-point Likert scale (1 = not relevant, 2 = slightly relevant, 3 = moderately relevant and 4 = highly relevant). Then, for each item, the I-CVI was computed as the number of nurses giving a rating of 3 or 4 divided by the number of nurses rating the item. The average S-CVI was computed by adding all I-CVIs and dividing the sum by the total number of items. An average S-CVI of 0.90 or higher indicates excellent content validity. The A-MESRT in this study had an average S-CVI of 0.96 and no item had to be adjusted.

Table 1: Definition and classification of medication errors according to Bates et al. (1999)

Process	Definition	Error types (Examples)
Ordering (handwritten)	Unambiguous prescription according to the five rights (right patient, medication, dose, application, time)	Illegible or incomplete prescription; omission of an order; wrong order such as wrong patient, wrong drug name, wrong drug formulation, wrong route, wrong dose regime and wrong application time
Ordering (by CPOE)	Unambiguous prescription according to the five rights (right patient, medication, dose, application, time)	Discrepancy in: the right medication such as drug name, right time, right dose, right patient, right route, and omissions of medications
Transcription (into the CPOE)	Identical transcription from the anaesthesia order to an EPR by an RN	Discrepancy in: the right medication such as drug name, right time, right dose, right patient, right route, and omissions of medications
Dispensing	Dispensing of medication according to a physician's order	Unordered drug (wrong drug); unordered time, unordered dose, wrong patient, unordered route, and omission of medications
Administration	The right medication in the right dose to the right patient in the right application form and at the right time	Wrong medication; wrong administration time (± 30, 60 and 120 min); wrong dose; wrong patient; wrong route; omission of a dose and unordered drug or dose

CPOE, computerised physician order entry; EPR, electronic patient record; RN, registered nurse.

Data collection process

Before data collection, all RNs received in-depth information about the purpose of the study from the principal investigator (PI) and were given explicit instructions on how to use the A-MESRT, including the possible responses to each question. The RNs were asked to complete an A-MESRT questionnaire after each ME and, if no errors occurred during their shift, to complete a questionnaire indicating that this had been the case. Consequently, each RN completed at least one A-MESRT during each shift. If more than one ME event occurred during the shift, the RN completed an A-MESRT for each event. Furthermore, the RNs were instructed that whenever they experienced high or very high workload, they should note their perceived reasons on the A-MESRT.

A supply of A-MESRTs and a box for collection of completed A-MESRTs were available on each participating ward. During the study period, the PI was available for any questions and offered support during the day-shift on weekdays. The A-MESRT does not report any personal data, so all participants remained anonymous.

Sociodemographic variables including age, gender, nursing education, overall work experience and work experience on the current ward were collected by means of a separate questionnaire one month before the start of the study. Patient data of interest were the number of inpatients on the given ward, surgical discipline, gender, age and the total number of operated patients. Patient data were collected retrospectively from the electronic patient record (EPR).

Medication process in study setting

As part of the full EPR, the community hospital uses a CPOE system, an eMAR, and an ADD in the medication process (Oertle, 2012). Hence, drug prescription, preparation and administration are a standardised electronic process for all units, except in the department of anaesthesia, where physicians primarily use handwritten medication orders on prescription sheets and RNs transcribe handwritten orders into the CPOE system. On regular wards, physicians enter medication orders directly into the CPOE system. After receiving a physician's order, RNs are responsible for preparing and administering the medication using ADD and eMAR systems and for monitoring the patient after medication administration. Hence, RNs are responsible for all steps in the medication process except ordering. Hospital pharmacy staffs are responsible for filling all ADDs systems. The surgical wards do not use technological support during medication administration.

Data analysis

Data were analysed using SPSS (V21.0, SPSS, Inc., Chicago, IL). Descriptive statistics were used to describe patient characteristics, RNs, ME frequency and type, patient consequences attributable to MEs and the reason for high or very high workload as reported by nurses. A binary logistic regression model featuring a forward stepwise process with an exclusion test was developed to determine two independent predictive variables: (1) nurses' reported workload and (2) work shift. The dependent variable was MAEs. A p-value of < 0.05 was considered to indicate a statistically significant difference.

Ethical considerations

As voluntary reporting and disclosure of MEs is potentially a highly sensitive issue amongst healthcare professionals, identity protection and confidential use of data were guaranteed. Participants provided written

informed consent before data collection, and self-reporting was voluntary during data collection. The study was approved by the hospital's institutional review board, because the Ethical Board of the State of Berne declared their organisation not to be responsible for the approval of this study.

RESULTS

Sociodemographic sample characteristics

Of 110 RNs, 88 participated in the study. A total of 1087 patients were hospitalised during the study period. Sample characteristics are listed in Table 2.

Frequency, type, causes and potential clinical consequences

Altogether, 1936 A-MESRTs were completed by RNs during the study period. In 1149 (59.3%) cases, no ME was reported, but 751 (38.8%) A-MESRTs contained accounts of various MEs. Thirty-six (1.9%) A-MESRTs were incomplete. Of the 751 reported MEs, 83 (11.1%) were preventable, whilst 11 (1.5%) had consequences for patients. These consequences included pain; physical manifestations such as coughing, excretion and fatigue; internal blood collection; or inadequate drug therapy with antibiotics or antiemetics. No patient suffered any more harmful consequences. The total number of each MEs (n = 861, 100%) during the medication process (excluding handwritten orders) were distributed as follows: 371 MEs (43.0%) occurred during medication administration, 198 (23.0%) during physician ordering and 292 (34.0%) during medication dispensing (Table 3). Of the 768 (100%) handwritten anaesthesia orders, 232 (30.2%) were erroneous: 96 (41.4%) were incomplete, 94 (40.5%) were illegible, 36 (15.5%) were wrong prescriptions and 6 (2.6%) were faulty transcriptions.

Of the 371 reported MEs that occurred during the administration of a medication, 291 (78.4%) were due to a medication being given at the wrong time. In physician ordering by the CPOE process, the most common form of ME was ordering of the wrong dose (n = 61, 30.8%), whilst in the medication dispensing process, 63.7% of errors were due to omission.

Nurses' reported workload and the frequency of medication administration errors

The nurses' reported workload was distributed as follows: 27 (1.4%) no workload, 530 (27.9%) low workload, 1005 (52.9%) medium workload, 298 (15.7%) high workload and 40 (2.1%) very high workload. The reported reasons for high or very high workload were (1) many newly operated patients to monitor; (2) complex multimorbid patients, for example, those with delirium; and (3) patients with complications after surgery.

The dependent variable in this study (MAEs) and the predictive variables (nurses' reported workload and work shift) were entered into the forward stepwise selection process of the binary logistic regression model, which converged into a significant model (χ^2 = 85.479, df = 1, $p < 0.001$, OR = 2.129, Nagelkerke R^2 = 0.068). The only significant predictive variable in the model was the

Table 2: Sample characteristics

Characteristics	
Registered Nurses	
Total number (%)	88 (100)
Female (N, %)	81 (92)
Male (N, %)	7 (8)
Age (years)	M = 31.8; SD = 9.5
Bachelor's degree(N, %)	7 (8)
Diploma (N, %)	81 (92)
Overall work experience (years)	M = 7.7; SD = 8.3
Work experience on current ward (years)	M = .8; SD = 5.0
Patients	
Total number (%)	1,087 (100)
Undergone surgery (N, %)	768 (70.7)
Female (N, %)	627 (57.7)
Male (N, %)	460 (42.3)
Age (years)	M = 62.0; SD = 18.4
Surgical disciplines (N, %)	
Orthopaedic	387 (35.6)
Visceral surgery	335 (30.8)
Spinal surgery	158 (14.5)
Urological	107 (9.8)
Gynaecological	94 (8.6)
Ear-nose-throat	6 (0.6)

M: mean; SD: standard deviation.

Table 3: Frequency and type of medication errors

	Medication administration 371 (43.0%) N (%)	Physician ordering (CPOE) 198 (23.0%) N (%)	Medication dispensing 292 (34.0%) N (%)
Wrong medication	30 (8.1)	19 (9.6)	19 (6.5)
Wrong time	291 (78.4)	58 (29.3)	48 (16.4)
Wrong dose	10 (2.7)	61 (30.8)	34 (11.6)
Wrong patient	7 (1.9)	1 (0.5)	3 (1.0)
Wrong route	4 (1.1)	19 (9.6)	2 (0.7)
Omission	29 (7.8)	40 (20.2)	186 (63.7)

nurses' reported workload, confirming a relationship between reported workload and the frequency of MAEs. An increase in workload by one unit (20%) on the Likert scale led to an increase in the likelihood of making an MAE by the factor 2.129.

DISCUSSION

The frequency, type and causes of MEs caused by RNs and physicians and their consequences for patients in all stages of a technology-supported medication process – including CPOE, eMAR, and ADDs – on six surgical wards were assessed during a two-month study period. These data showed that nurses' workload is a significant predictor for MAEs: the heavier the workload, the greater is the relative probability of making an MAE. Furthermore, the three main reasons for high or very high workload from the nurses' point of view were ascertained. A novel reporting method – the A-MESRT – that rigorously respects anonymous reporting by RNs was successfully implemented. The A-MESRT is easy to use, and it is clear for RNs what has to be reported as an ME.

The highest rate of MEs caused by nurses and physicians occurs in the non-technologically supported steps of medication administration (43%) and handwritten orders (30%), compared with the technologically supported steps of dispensing (34%) and physician ordering using a CPOE system (23%). These findings demonstrate the strengths of a technology-supported medication system.

Medication administration error rate

In comparison with previous studies, the error rate in this study varied considerably in some steps of the medication process. Although the community hospital uses a high level of new technology in order to prevent MEs, the data showed that MEs still occur. The overall proportion of MEs accounted for by MAEs in this study (43%) is comparable with the results of other studies of institutions that did not use technologically supported medication administration. Küng et al. (2013) reported that 58% of MEs were MAE, and Bates et al. (1995) reported a rate of 34%. Both of these studies also used a self-reporting tool, in contrast to Leape et al. (1995) who detected the rate of MAEs through interviews as 38%. These data clearly demonstrate the importance of the last step in the medication use process and highlight the need for highly reliable strategies such as barcoded medication administration in order to ensure safe administration of medication. Several studies have shown that barcoded medication administration is able to reduce MAEs significantly (Johnson, Carlson, Tucker & Willette, 2001; Poon et al., 2010).

Errors in timing of administration (78.4%) were the most common type of MAE. In this study, a timing error was defined as administration more than 30 min before or after the scheduled time. Hence, the high rate of timing errors may be related to the definition used. Interestingly, no explicit recommendations regarding timing errors could be found in the literature. However, this definition of timing errors was in accordance with previous studies (Barker et al., 2002; Poon et al., 2010).

Computerised physician order entry versus handwritten ordering

The finding that 23% of MEs occurred in the physician ordering stage using a CPOE system differs from previously published results: Bates et al. (1995) reported 56%; Leape et al. (1995), 39%; and Küng et al. (2013), 29%. The lower rate of ordering errors in this study may be attributable to the use of a CPOE system, which was not part of the medication process in any of the other studies. Errors during ordering were reported less frequently with CPOE systems than with the handwritten orders in the anaesthesiology department (30.2%). The high number of errors during handwritten ordering is primarily due to incomplete (41.4%) or illegible (40.5%) anaesthesia orders. In this respect, the findings are similar to those of other studies in which a decrease in MEs was achieved by the use of a CPOE system compared with handwritten orders (Bates et al., 1998; Shulman et al., 2005). This study showed that a change from handwritten ordering to a CPOE system – combined with other technologies – may considerably reduce MEs and should be implemented in the anaesthesiology department to improve overall medication safety. Nevertheless, a nurse-reported proportion of 23% of all MEs in the context of CPOE systems is still high and shows that the use of an even higher standard of technology in the medication process needs to be explored (Koppel et al., 2005; Strom et al., 2010).

Automated dispensing devices

The high proportion dispensing errors (34%) amongst total MEs – especially given the presence of well-implemented standard ADD systems on the study wards – needs to be discussed. The majority of reported errors during dispensing of medication were errors of omission (63.7%). These high numbers of errors are systematic reporting errors, because the processes of medication ordering and medication dispensing can be several hours apart. Hence, most of these errors are false-positive reported omission errors because of the self-reporting method used in the study.

Nurses' reported workload

Finally, the results indicate that there is a significant correlation between the reported workload of RNs and the prevalence of MAEs and that certain aspects of the work environment may influence MEs. The OR in this study was 2.129, and the effect size in the model was between small and medium. According to Cohen (1992), the effect size may be used to determine the relative probability. This means that if the workload increases by one unit (20%) on the Likert scale, the relative probability of making an MAE increases by up to 112.9%. In order to achieve a higher effect size a larger sample should be used in further studies. Moreover, this study revealed, from the nurses' point of view, the three main reasons for high or very high workload: (1) the large numbers of newly operated patients for nurses to monitor. This agrees with the data of Aiken et al. (2012), who reported that nurses' workload increased with an increased ratio of patients to nurses; (2) having to care for complex multimorbid patients, for example, those with delirium; and (3) responsibility for patients with complications after surgery, in line with findings from other studies that nurses' workload appeared an important contributor to MAEs owing to factors such as instability of patients' condition, multitasking and inadequate attention (Eslamian et al., 2011; Keers et al., 2013b; Kohn et al., 2000).

However, further studies of nurses and other healthcare professionals are required to explore more predictive variables that may have an impact on the workload relating to MAEs. Furthermore, these data demonstrate that the medication process does not dependent on a single profession. Rather, it demonstrates that all health professionals – RNs, physicians, anaesthesia and pharmacists – are needed and each profession makes an important contribution in all steps of the medication process. This interaction between the health professionals demands further improvement to make the medication process safer. Therefore, further research is needed to investigate the point of view of every involved health profession in the medication process.

Strengths and limitations

This study is the first from a Swiss acute care hospital to provide valuable data on MEs caused by nurses and physicians at every stage of a technology-supported medication process, together with the correlation of nurses' reported workload to MAEs and the nurses' perceived reasons for high workload. Furthermore, the included wards provided a comprehensive overview of the different surgical disciplines at a Swiss acute care community hospital. In this study, all RNs working on the units during the data collection period were included and eligible to participate. However, despite these strengths, some limitations also need to be considered.

First, it is difficult to compare the results to those of other studies owing to the different methods of detection used for MEs, different statistical analyses, various ME definitions and error categories, heterogeneous settings and the varying use of technology in the medication process. This study used the most common definition, according to Bates et al. (1999), to enable the highest possible comparability. Second, in one-third of the wards, pharmacists dispensed the medication instead of RNs. Although the analyses did not show differences amongst the participating wards, it is possible that RNs checked the medications differently depending on whether a pharmacist or an RN had dispensed them. Third, further research is required to analyse the tool used, the A-MESRT. It is, therefore, recommended that this study should be replicated using a larger sample over a longer period of time in acute care settings, because a short data collection period may not have been representative of the usual ME events. Moreover, the reporting of MEs with a customised A-MESRT may represent some degree of underestimation owing to the fact that not all MEs are consciously detected by RNs. In addition, it may happen that reporting of MEs is more likely to be forgotten if the workload is increased or too low. On the other hand, an ME can also be the reason for a high workload. Therefore, direct observation would be an additional method to obtain more valid and objective data because the self-report instrument includes the subjectivity of the RNs. Furthermore, evaluation by means of content validity testing is a well-accepted means for clinicians and researchers who require high-quality measurements, but further verification of the evidence as response processes, internal structure, relations to other variables and consequences of testing is needed. Furthermore, it is necessary to use the A-MESRT with all health professionals of the medication process to obtain an integral view. Fourth, the omission rate of 63.7% during medication dispensing is very high and generally due to self-reporting errors, which may lead to an over-reporting of events. Finally, this study explored only the nurses' reported workload, but further studies are highly warranted to investigate physicians' perception of their workload. Finally, our data cannot be generalised because of the observational design and the methods used in our study.

CONCLUSIONS

The use of the A-MESRT, an adapted method for identification of MEs caused by nurses and physicians at all stages of a technology-supported medication process,

together with the correlation of nurses' perceived workload to MAEs, proved effective. According to these data, a technological support at every stage of the medication process helps to achieve a high standard of patient safety. Therefore, the use of new technologies such as CPOE, BCMA, ADDs and eMAR should be implemented systematically throughout Swiss hospitals in order to prevent MEs and should be closely evaluated. However, to enhance the safety in the medication process, further research is required to show the view of all health professionals involved. Therefore, the A-MESRT needs to be further evaluated and adapted for different health professionals. Finally, our results demonstrate a correlation between the number of MAEs and nurses' reported workload, which might be an important predictor with respect to a safe nursing work environment. The three main reasons for high or very high workload from the nurses' point of view were (1) many newly operated patients to monitor; (2) complex multimorbid patients, for example, those with delirium; and (3) patients with complications after surgery. Recognition of the causes of nurses' workload enables the design and implementation of appropriate interventions to minimise their occurrence and improve medication safety.

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APPENDIX

Table 4: Medication Error Self Reporting Tool (adapted from Küng et al., 2013)

During my shift, one of the following medication-error-related events occurred (please mark with a cross)

Medication administration	□	1. I administered a ***wrong medication*** to a patient
		2. I administered a medication at the ***wrong time***: □ More than ***30 min*** earlier or later than ordered □ More than ***60 min*** earlier or later than ordered More than ***120 min*** earlier or later than ordered
	□	3. I administered a medication in a ***wrong dosage***
	□	4. I administered a medication to the ***wrong patient***
	□	5. I administered a medication in the ***wrong route***
	□	6. I ***forgot*** to administer a medication
Physician ordering with CPOE	□	7. A ***wrong*** medication was prescribed
	□	8. A medication prescription was ordered at the ***wrong time***
	□	9. A medication prescription was ordered in a ***wrong dosage***
	□	10. A medication prescription was ordered to the ***wrong patient***
	□	11. A medication prescription was ordered the ***wrong route***
	□	12. A medication was ***forgotten*** to prescribe
Medication dispensing	□	13. At the medication control ***a prescribed medication was not dispensed***
		14. At the medication control I have found the following error: □ A ***wrong*** medication was dispensed □ A medication was dispensed at the ***wrong time*** □ A medication was dispensed in a ***wrong dosage*** □ A medication was dispensed to the ***wrong patient*** □ A medication was dispensed in ***wrong route***
Anaesthesia ordering		15. Have you controlled a prescription by anaesthesia during your shift pre-or postoperatively? □ **Yes** (if yes, please go to question **10**, **11**, **12** and **13**) □ **No** (please continue with question **14**)
	□	16. A medication prescription by anaesthesia was ***illegible***
	□	17. A medication prescription by anaesthesia was ***incomplete***
	□	18. A medication prescription by anaesthesia was ***wrong***
	□	19. A medication prescription by anaesthesia was ***transcribed wrong***
Patient consequences	□	20. The medication error event had ***no consequences*** for the patient
	□	21. The medication error event had ***consequences*** for the patient. If yes, what are the consequences? (use the space below)

Continued *Table 4: Medication Error Self Reporting Tool (adapted from Küng et al., 2013)*

Workload		22. Please evaluate your workload of the ***present shift***:
		 Very high workload □ |  High workload □ |  Medium workload □ |  Low workload □ |  No workload □
		23. If the workload was ***high*** or ***very high***, please write down the reason:
Shift	□	24. ***No*** medication error-related event happened to me during my shift
		25. Please mark your ***shift***:
		Morning shift □ | **Evening shift** □ | **Night shift** □

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