JAMIA Open, 2024, **7(4)**, ooae103
https://doi.org/10.1093/jamiaopen/ooae103
Research and Applications

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Risk factors for wrong-patient medication orders in the emergency department

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Abstract

Objectives: This paper investigates the risk factors for wrong-patient medication orders in an emergency department (ED) by studying intercepted ordering errors identified by the "retract-and-reorder" (RaR) metric (orders that were retracted and reordered for a different patient by the same provider within 10 min).

Materials and Methods: Medication ordering data of an academic ED were analyzed to identify RaR events. The association of RaR events with similarity of patient names and birthdates, matching sex, age difference, the month, weekday, and hour of the RaR event, the elapsed hours since ED shift start, and the proximity of exam rooms in the electronic medical record (EMR) dashboard's layout was evaluated.

Results: Over 5 years (2017-2021), 1031 RaR events were identified among a total of 561 099 medication orders leading to a proportional incidence of 184 per 100 000 ED orders (95% CI: 172; 195). RaR orders were less likely to be performed by nurses compared to physicians (OR 0.54 [0.47; 0.61], $P < .001$). Furthermore, RaR pairs were more likely to have the same sex (OR 1.26 [95% CI 1.10; 1.43], $P = .001$) and the proximity of the exam rooms was closer (−0.62 [95% CI −0.77; −0.47], $P = .001$) compared to control pairs. Patients' names, birthdates, age, and the other factors showed no significant association ($P > .005$).

Discussion and Conclusion: This study found no significant influence from factors such as similarity of patient names, age, or birthdates. However, the proximity of exam rooms in the user interface of the EMR as well as patients' same sex emerged as risk factors.

Lay Summary

This study explores why mistakes happen when ordering medications for patients in an emergency department (ED). Specifically, it looks at instances where doctors or nurses accidentally order medication for the wrong patient but then quickly correct it. The research examined various factors that might contribute to these errors, such as patients having similar names or birthdates, being the same sex, or if their exam rooms are close in the hospital's computer system's screen layout.

Over 5 years, there were 1031 such mistakes out of over 561 000 medication orders. The study found that errors were less likely to be made by nurses compared to doctors. It also discovered that these errors were more common when patients were of the same sex and when their exam rooms were close to each other on the computer screen. However, factors like patient names, birthdates, and ages did not significantly affect the likelihood of these mistakes. The findings suggest that certain features in the hospital's computer system and patient characteristics might increase the risk of medication ordering errors.

Key words: emergency medicine; medication error; retract-and-reorder (RaR); electronic medical records (EMRs).

Introduction

Safeguarding patients from preventable harm is a key objective in health care. This target has been emphasized by many national and international initiatives such as the WHO's Medication Without Harm Initiative.[1] However, medication errors, that is, the failure to provide the right patient with the right medication in the right dosage at the right time for the right reason, contribute a substantial fraction of preventable harm in health care.[2]

The emergency department (ED) is characterized by high workload and time pressure, concurrent care of multiple severely ill patients, restricted space and crowding, frequent interruptions, and high ordering rates of drugs and procedures. These conditions make the ED a "danger zone" for patient safety in general and medication safety in particular.[3,4] Pharmacists in the ED detected 7.8 medication errors per 100 patients (2.9 errors/100 medications) through direct observation.[5] Higher intensity of crowding has been associated with preventable adverse events and medication errors.[6,7] Emergency department physicians' error rates during prescribing increase significantly with interruptions and multitasking and below-average sleep.[8] Emergency department

Received: November 14, 2023; **Revised:** June 25, 2024; **Editorial Decision:** September 19, 2024; **Accepted:** September 24, 2024

physicians spent a considerable fraction of their time managing several patients concurrently which could be a driver for patient misidentification errors.[9]

Wrong-patient order entry (WPOE) in which a prescription is intended for patient *A* but accidentally entered for patient *B* are a subset of medication errors and serious safety events with high harm potential for *both* patients.[10] Our understanding of wrong-patient orders in the ED is still limited as they are difficult to identify using common methods for medication error detection. They require the pairing of two sets of information: An omitted order for patient *A* and a simultaneous wrong order for patient *B*. Critical incident reporting systems (CIRS) can overcome this problem but are subject to underreporting and bias.[11] In a recent analysis of serious medication errors in the ED reported to the Pennsylvania Patient Safety Reporting System between 2011 and 2020, 5.6% were wrong-patient orders.[12]

Electronic medical records (EMR) and computerized provider order entry (CPOE) have been identified as contributing to wrong-patient orders,[13,14] but also offer the opportunity to study them due to the availability of large datasets of detailed ordering data with time stamps and provider identification.[15] Koppel et al[16] found that the design of CPOE systems can contribute to medication errors with 55% of physicians participating in that study reporting difficulty identifying the patient they were ordering for.

Adelman et al[10] suggested a "retract-and-reorder" (RaR) indicator to identify near-miss wrong-patient orders in electronic ordering data. The RaR measure is defined as an order placed by a provider for a patient, canceled by the same provider, and reordered unmodified for a different patient within a specified time frame, usually 10 min. The RaR rule thus detects near-miss patient misidentification orders of which the provider became aware of and corrected it promptly after placing the initial order. Retract-and-reorder has been found to be the most widely used method to identify WPOE. The positive predictive value of the RaR marker has been established using provider interviews and clinical review and reports and ranges between 76% and 80%, making it a valid and useful metric.[17,18]

The US National Quality Forum endorsed RaR as health IT patient safety measure (NQF Measure #2723).[19] The RaR measure has been applied to obstetrics and maternity care,[18,20] neonatology,[21] radiology,[22] and to entire hospital systems.[10,23]

Three studies explicitly applied the RaR indicator to the emergency medicine setting as outcome measure for interventions aimed at intercepting wrong-patient errors: Green et al[24] investigated the effects of a specific patient verification dialog on wrong-patient orders in the ED. The authors report a mean wrong-patient order rate of 202/100 000 orders prior to the intervention, of which 21% were medication orders. The intervention was moderately effective with a 25% reduction of wrong-patient orders sustained after 2 years. In 2020, Salmasian et al[25] investigated whether the display of patient photographs in the EMR could reduce wrong-patient orders, measured by the RaR indicator. The reported RaR rate was 186/100 000 orders without patient photographs and 133/100 000 orders when a patient photograph was in the EMR. After adjustment, patients with photographs had a significantly lower risk for RaR events (OR, 0.57; 95% CI, 0.52-0.61). Finally, Kannampallil et al[26] used interrupted time series analysis to study the association of the number of allowable open patient charts and RaR events in the ED. The rate of intercepted wrong-patient medication orders was 83.7/100 000 and was unaffected by the number of allowed open charts.

In the mentioned studies, the RaR metric is used mainly as outcome measure to evaluate the effects of policies and (IT-) measures to prevent wrong-patient orders. However, RaR events can also be used to identify, characterize, and contribute to understanding intercepted wrong-patient medication orders. The main aim of our study was thus to identify risk factors for wrong-patient medication orders identified by the RaR metric in a large academic ED to provide the evidence needed to develop targeted safeguarding strategies.

In a study involving a large number of inpatient orders in a pediatric setting, Levin et al[27] established the following risk factors for wrong-patient orders: patient age, last name spelling, bed proximity, medical service, time/date of order, and ordering intensity. Building on this experience, we analyzed the association of the following potential risk factors with RaR events: indicators of similarity of affected patients (patient names, birthdates, age, and sex), indicators of exhaustion of ordering staff (month, weekday, and hour at which the RaR event occurred, hours since providers' shift start, assignment to both patients involved), and proximity of affected patients' exam room representation in the EMR dashboard screen.

Methods

Setting

This study is a retrospective analysis from the ED of the Bern University Hospital, Switzerland. Our ED is a tertiary care center, caring for a patient population of around 2 million and treating around 55 000 adult patients each year with an interdisciplinary and interprofessional team. At the time of the study, our ED had a total of 38 examination rooms, which are designed to accommodate one patient at a time.

In Switzerland, nurses are allowed to order and administer a variety of drugs, such as paracetamol, fentanyl, or ondansetron based on defined protocols. Additionally, when physicians verbally instruct nurses to administer a medication without entering it into the EMR themselves, the nurses enter these verbal orders into the system, and these orders are attributed to nurses. Those orders are later cosigned by a physician. In addition, patients are usually started on IV fluids by nurses, also based on protocols. Therefore, orders placed by nurses and physicians (attending and resident emergency physicians) were included. However, medications ordered by protocol or based on a physician's verbal order cannot be discriminated by algorithm.

Our ED uses the E.care EMR (Mesalvo Turnhout BV, Belgium), which is used by approx. 64 hospitals throughout Europe and allows for admission and discharge, clinical documentation and incorporates CPOE for medication, investigations such as X-rays and nursing tasks. Patients and their respective exam rooms are represented on a dashboard. Patients for which the logged-in physician or nurse is responsible are highlighted in the system (as exemplified by the different background color for exam rooms K-10, K-13, K-21a, and K-24b, see Figure 1: ED layout). The system allows for only one patient's record to be open at a time for clinical documentation or ordering.

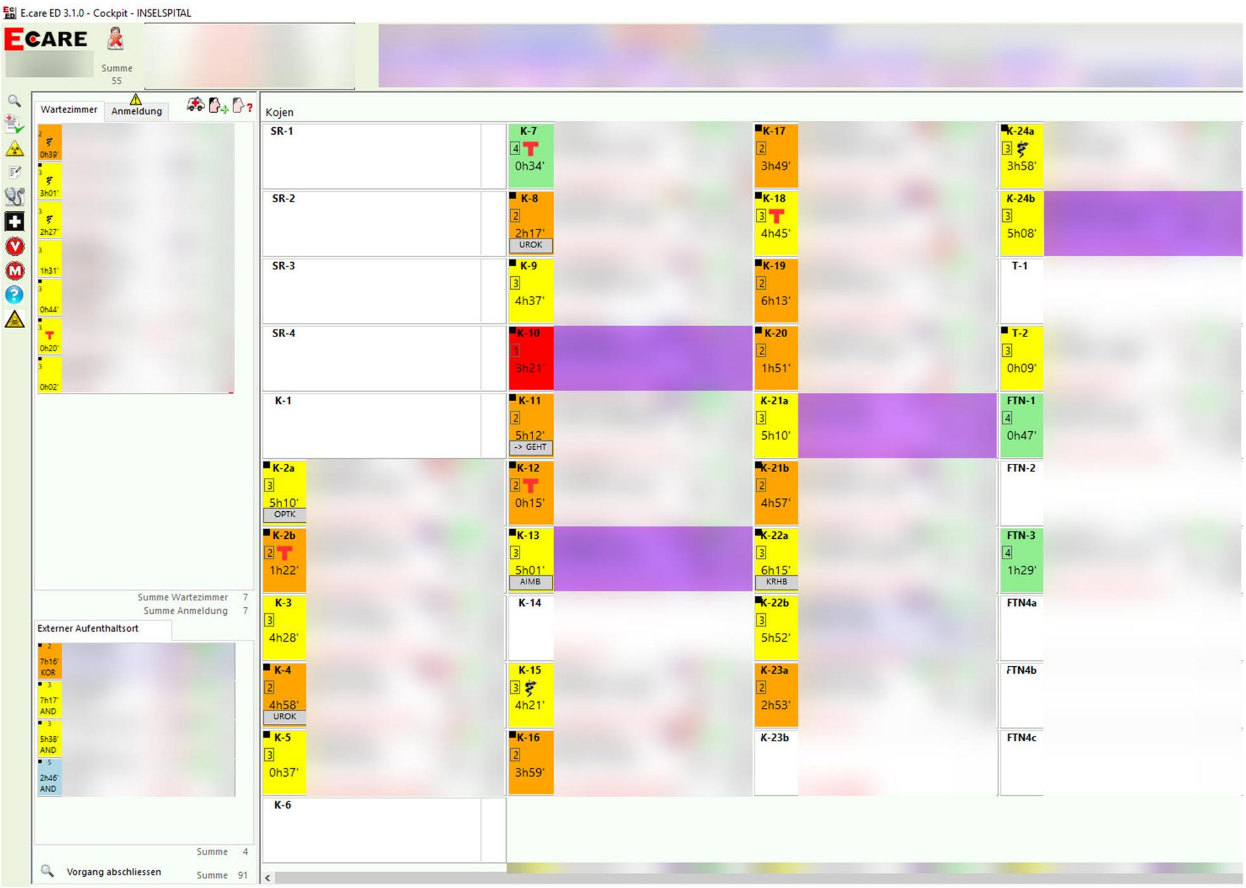

Figure 1. EMR dashboard screen (patients treated by the logged-in health care professional are highlighted in the system). EMR, electronic medical record.

Data extraction

Patient and medication data from 2017 to 2021 were extracted from the ED's EMR database. Using SQL Server Management Studio (Microsoft, Seattle, USA), database queries were performed and data were anonymized. For the subsequent analysis of similarity of names and birthdates, these data columns were evaluated separately from other data.

Ethical considerations

This study was classified as a quality evaluation study by the local institutional review board (KEK-2022-01333) and the need for informed consent was waived.

Identifying RaR events

According to its original definition, RaR events were defined as a retracted order followed by a new, but identical medication order (same drug and dosage) for any other patient within 10 min by the same provider. In this study, we also included events with the reverse sequence (ie, medication orders that were followed by a matching retraction within 10 min). It is important to note that we only included intercepted wrong-patient orders, the medication was therefore not administered.

Medication orders in our system contain a unique code which was used to identify the ordered drug. To verify whether the same health care provider (HCP) was assigned for both patients involved, the clinical information system's log was checked for patient assignment. The resulting pairs of retracted and reordered medication orders were analyzed for their association with potential risk factors.

Potential risk factors

The medication's ATC code (Anatomical Therapeutic Chemical) was assigned using a Swiss formulary (HCI Solutions, Bern, Switzerland) with the aforementioned code as a reference and drugs were classed by therapeutic groups.

To determine the similarity of patient names, the last name and first name of both patients in the RaR pair were compared using the Levenshtein distance algorithm (as suggested by Levin et al[27]), which was implemented as a module in the statistical software package STATA.[28] The Levenshtein distance is defined as the minimum number of edits (insertions, deletions, or substitutions) required to change one sequence/name into another. As there is no agreed threshold for comparing Levenshtein distances in short string sequences such as names, we defined a threshold of 3 and less to define "similar names". Thus, less than 3 positions in the first and last names of the RaR patient pairs would have to be changed to be equal, for example, "Weesman to Freeman". The same Levenshtein metric was used when comparing birthdates (in the German date format "mm.dd.yyyy"). Matching sex for the pair of patients and their age difference in years was also assessed. The age difference was grouped into four classes (0-4, 5-9, 10-19, and 20-100 years).

Month, weekday, and time of day (hour) of the RaR event were assessed. In addition, months were grouped by seasons (winter, spring, summer, and autumn) and hours by shifts (day [8-16 h], late [17-23 h], night [0-7 h]). The time of retraction and reorder in relation to the start of the HCP's shift was calculated in hours using staff rosters (0-8 h were used since physicians and nurses are working in three shifts per day).

The proximity of exam rooms was assessed as represented in the EMR dashboard's screen layout, which displays exam rooms in rows and columns (Figure 1). The distance between exam rooms was calculated adding the absolute difference of the exam room's column and row number. The EMR dashboard displays the following information: exam room, patient's last name and first name, sex, age (but not date of birth), main symptom, and time since arrival.

Medication's potential for harm

The "potential for harm" of medications in was independently assessed by two study physicians (G.K. and T.C.S.) and classified as "without clinical significance", "clinically significant", "serious", or "life-threatening" as proposed by Poon et al.[29] To this end, all distinct medications administered in our ED were classified and the resulting code was stored in a lookup table and matched to RaR and non-RaR medication orders.

Statistical analysis

Statistical analysis was performed with the STATA software suite version 16 (StataCorp LLC, College Station, TX, USA). RaR events and their potential for harm were analyzed using descriptive statistics. A distribution of a continuous parameter was described with the median as measure of central tendency accompanied by the interquartile range (25th percentile; 75th percentile) as most parameters were not normally distributed. Categorical variables were described with the absolute number accompanied by percentage. Some distributions of continuous variables were displayed graphically with a histogram. Furthermore, the frequency of errors among staff was plotted to determine whether a small group of HCPs was responsible for a large fraction of RaR events. To obtain a 95% CI for the proportional incidence Stata's—*cii*—command was used. The identified retracted order of an RaR event was compared to a non-RaR event using univariable logistic regression for the studied categorical variables.

To make sure that no random effects distorted the comparison of similarities of sex, age, birthdate, and names as well as exam room proximity for RaR pairs, we paired these events with controls. To this end, we randomly selected 10 other medication orders from the database that matched the retracted order by order hour. Orders for patients treated in the same exam room as the original RaR patient were not included in the random samples, as the exam room proximity of this pair would be zero, which does not occur in the original RaR pairs.

We compared the pair characteristics of the RaR and control pairs using conditional logistic regression (binary outcomes) and a mixed linear regression model (continuous outcomes), respectively. All effect sizes were presented with 95% CI. To adjust for multiple testing, the *P*-value of significance was set to $P < .005$.

Results

Within the 5 years from 2017 to 2021, a total of 1031 RaR events were identified out of a total of 561 099 orders (184 per 100 000 orders [95% CI: 172; 195]).

The distribution of the retracted and reordered drugs by therapeutic group (ATC) is shown in Figure 2. Perfusion solutions, analgesics, and antibacterial medications were the most often ATC codes of RaR pair medications with 19.4%, 19.1%, and 13.1%, respectively.

A total of 1510 staff members were involved in placing medication orders. The 1031 RaR orders were placed by a group of 380 staff members with up to 17 RaR orders being performed by a single staff member; 30% of all RaR events were made by staff with more than 5 RaR events (Figure 3).

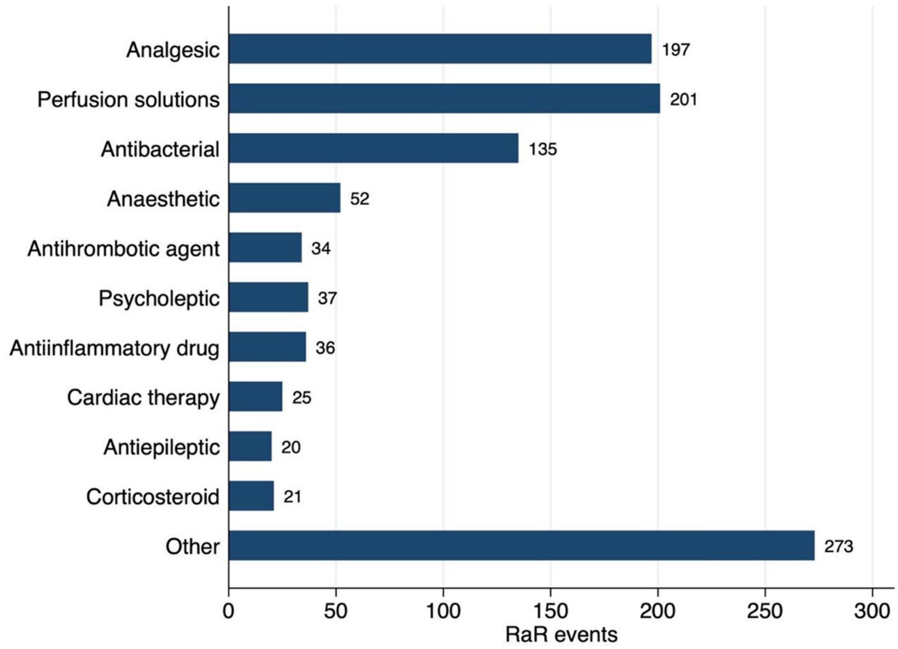

Figure 2. Frequency of RaR events according to therapeutic group ($n = 1031$). RAR, retract-and-reorder.

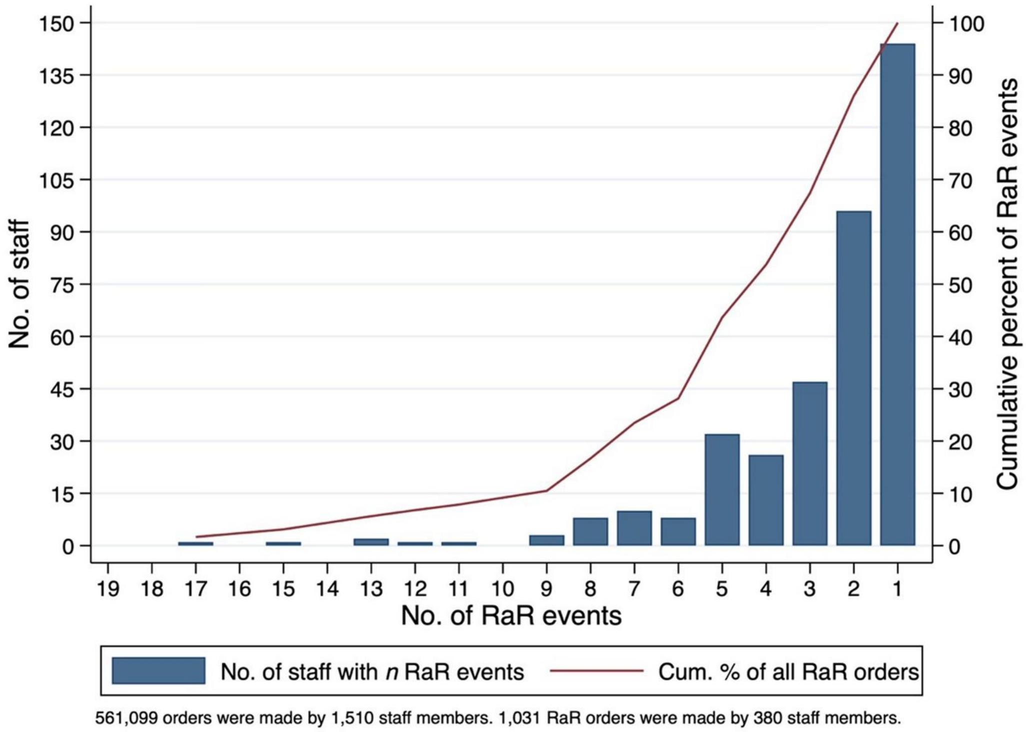

Figure 3. Distribution of RaR events among staff. RAR, retract-and-reorder.

Table 1 shows the characteristics of retracted orders of identified RaR pairs and non-retracted orders. Retract-and-reorder orders were less likely to be performed by nurses compared to physicians (OR 0.54 [0.47; 0.61], $P < .001$). All other studied parameters did not differ between cases and controls. The RaR event's distribution across months and hour of day showed no statistically significant differences (Table 2).

The characteristics of RaR pairs and control pairs are shown in Table 3. Retract-and-reorder pairs were more likely to have the same sex (OR 1.26 [95% CI 1.10; 1.43], $P = .001$) and the proximity of the exam rooms on the EMR dashboard's screen layout was closer (−0.62 [95% CI −0.77; −0.47], $P = .001$) compared to control pairs.

Patients' names or birthdates and other factors like patient's age, monthly distribution, and time of RaR events showed no significant association ($P > .005$). The distributions of similarity of first name, last name, date of birth, and exam room proximity according to case or control pair are shown in Figure 4.

A subgroup analysis was performed which included only medication orders with a potential for harm classed as "serious" and "life-threatening". This did not alter the results.

Discussion

Contributing factors

A variety of factors may contribute to ordering errors, including cognitive, organizational, environmental, and technological factors and their interplay.[30] Only a few studies have focused on RaR events specifically. Isaacs et al[31] have found higher event rates during "cold months", a finding we could not replicate. In this study, we could not discern any differences relating to weekdays (Mondays and Tuesdays had the highest frequency of errors in Isaac's study). The hour of the day was not a contributing factor to RaR events, whereas Isaacs et al[31] found a peak of events around 7 AM and 7 PM.

We expected that RaR events would have occurred in the later hours of a physician's or nurses' shift. However, that was not the case, as errors were rather evenly distributed throughout the shift. We attribute this to the comparatively high level of staffing in Switzerland and good working conditions and the fact that especially physicians tend to finish their existing patient's paperwork toward the end of their shift and thus order less in that period. This is also supported by the comparatively low number of RaR events overall (184 per 100 000 orders). It seems likely that high workload affects both, frequency of wrong-patient medication errors and staff performance to detect them within short period of time. While medication errors would rise with higher workload, the detection rate would drop, leaving the RaR metric more or less unaffected.

In another study, the restriction of the number of concurrently open records in the EMR was not significantly associated with RaR events. In our study, open record policy could not have affected RaR frequency since our information system only allows for one record to be open at a time.[23]

Few other studies have previously evaluated the similarity of patient names, sex, age, and date of birth as factors contributing to wrong-patient medication orders. While the setting in the study by Levin et al[27] was different, they found similarities in patient age and last name spelling to be associated with orders on misidentified patient events, something we could not find in our data.

Based on our results, the proximity of exam rooms (in the ED's actual floor design as well as the screen layout of our EMR's dashboard) appears to be the most relevant risk factor for RaR events. Patients cared for by the same provider in the

Table 1. Frequencies and percentages of retracted and non-retracted orders and the odds rate ratio (OR) with 95% CI by potential risk factors.

	Non-retracted order (total number $n = 560\ 068$)		Retracted order (total number $n = 1031$)		OR [95% CI]		*P*
Shift							
Day shift (8-16)	195 310	[34.9]	355	[34.4]	1.00	[base]	
Late shift (16-24)	246 616	[44.0]	457	[44.3]	1.02	[0.89; 1.17]	.785
Night shift (24-8)	118 142	[21.1]	219	[21.2]	1.02	[0.86; 1.21]	.819
Order 4-6 AM							
No	525 128	[93.8]	963	[93.4]	1.00	[base]	
Yes	34 940	[6.2]	68	[6.6]	1.06	[0.83; 1.36]	.636
Order weekday							
Mon	82 236	[14.7]	157	[15.2]	1.00	[base]	
Tue	78 922	[14.1]	156	[15.1]	1.04	[0.83; 1.29]	.759
Wed	78 463	[14.0]	148	[14.4]	0.99	[0.79; 1.24]	.916
Thu	76 102	[13.6]	131	[12.7]	0.90	[0.71; 1.14]	.382
Fri	79 345	[14.2]	153	[14.8]	1.01	[0.81; 1.26]	.930
Sat	81 795	[14.6]	131	[12.7]	0.84	[0.67; 1.06]	.138
Sun	83 205	[14.9]	155	[15.0]	0.98	[0.78; 1.22]	.829
Season							
Winter	132 540	[23.7]	280	[27.2]	1.00	[base]	
Spring	138 431	[24.7]	243	[23.6]	0.83	[0.70; 0.99]	.035
Summer	149 449	[26.7]	268	[26.0]	0.85	[0.72; 1.00]	.055
Fall	139 648	[24.9]	240	[23.3]	0.81	[0.68; 0.97]	.019
Hours since shift start							
0	49 827	[8.9]	94	[9.1]	1.00	[base]	
1	51 548	[9.2]	83	[8.1]	0.85	[0.64; 1.15]	.293
2	52 451	[9.4]	73	[7.1]	0.74	[0.54; 1.00]	.051
3	53 446	[9.5]	90	[8.7]	0.89	[0.67; 1.19]	.442
4	55 882	[10.0]	118	[11.4]	1.12	[0.85; 1.47]	.415
5	54 140	[9.7]	116	[11.3]	1.14	[0.87; 1.49]	.360
6	57 121	[10.2]	115	[11.2]	1.07	[0.81; 1.40]	.640
7	54 745	[9.8]	103	[10.0]	1.00	[0.75; 1.32]	.985
8	16 896	[3.0]	26	[2.5]	0.82	[0.53; 1.26]	.358
9	3588	[0.6]	5	[0.5]	0.74	[0.30; 1.82]	.510
10	110 424	[19.7]	208	[20.2]	1.00	[0.78; 1.27]	.990
Staff group							
Physician	200 628	[35.8]	526	[51.0]	1.00	[base]	
Nurse	359 440	[64.2]	505	[49.0]	0.54	[0.47; 0.61]	*<.001*
Medication error risk classification							
No clinical significance	44 300	[7.9]	75	[7.3]	1.00	[base]	
Clinically significant	370 027	[66.1]	639	[62.0]	1.02	[0.80; 1.30]	.871
Serious	132 019	[23.6]	285	[27.6]	1.28	[0.99; 1.64]	.061
Possibly life-threatening	13 722	[2.5]	32	[3.1]	1.38	[0.91; 2.08]	.130

ED are highlighted in our system, making misidentification errors among those patients more likely. Indeed, most patients involved in the RaR events were cared for by the same health care professional. Also, the sluggish response time when opening a patient's order screen without visual feedback of the patient's selection leads to users clicking multiple times, increasing the risk of accidentally selecting another patient. However, we expected that there still would have been a higher rate of similar names or matching sex among the RaR patient pairs. This indicates that our staff did not check patient details after patient selection in the EMR's dashboard.

Mitigation strategies

Among the measures suggested to mitigate medication misidentification errors, the display of patient photographs in the EMR was found to significantly reduce wrong-patient order entry.[25] However, this is not possible in all systems and—at least in Switzerland—it is unusual to obtain photographs of patients in emergency departments.

Others report that an "ID-verify alert" during the electronic order process reduced the odds of an RaR event (OR 0.84, 95% CI 0.72-0.98), while an "ID-reentry function" reduced the odds by an even larger magnitude (OR 0.60, 95% CI 0.50-0.71).[10] Likewise, Green et al[24] could show that a patient-verification dialog at the beginning of each ordering session was able to reduce the rate of wrong-patient orders in a CPOE system. Unfortunately, most systems do not allow to configure such safeguards.

Limitations

Timestamps in our ED's EMR are not always accurately set, especially during times of high workloads. Retrospective order entry therefore bears the risk of missed RaR events as the 10-min threshold may be missed.

Our finding that RaR orders were less likely among nurses should be interpreted with caution. As nurses are more likely to order by protocol, and often take verbal orders from doctors, our finding may reflect the type of ordering process rather than the profession of the ordering staff.

In this study, we also could not differentiate between true RaR events and orders with incidental co-occurrence. For example, patient *A* may have been ordered a normal saline infusion upon arrival as part of a protocol, which was found not be needed as the patient had already been started on an

Table 2. Frequencies of RaR and non-RaR events and the odds rate ratio according to order hour and month.

	Non-retracted order ($n = 560\ 068$)		Retracted order ($n = 1031$)		OR [95%CI]		*P*
Order hour, *n* (%)							
0	23 184	[4.1]	43	[4.2]	1.00	[base]	
1	19 531	[3.5]	34	[3.3]	0.94	[0.60; 1.47]	.783
2	16 267	[2.9]	29	[2.8]	0.96	[0.60; 1.54]	.869
3	13 738	[2.5]	25	[2.4]	0.98	[0.60; 1.61]	.940
4	12 101	[2.2]	28	[2.7]	1.25	[0.77; 2.01]	.363
5	11 041	[2.0]	19	[1.8]	0.93	[0.54; 1.59]	.786
6	11 798	[2.1]	21	[2.0]	0.96	[0.57; 1.62]	.877
7	10 482	[1.9]	20	[1.9]	1.03	[0.60; 1.75]	.917
8	14 249	[2.5]	23	[2.2]	0.87	[0.52; 1.44]	.591
9	17 677	[3.2]	26	[2.5]	0.79	[0.49; 1.29]	.351
10	21 730	[3.9]	32	[3.1]	0.79	[0.50; 1.26]	.323
11	25 705	[4.6]	43	[4.2]	0.90	[0.59; 1.38]	.633
12	26 753	[4.8]	52	[5.0]	1.05	[0.70; 1.57]	.820
13	28 250	[5.0]	49	[4.8]	0.94	[0.62; 1.41]	.749
14	28 523	[5.1]	64	[6.2]	1.21	[0.82; 1.78]	.335
15	32 423	[5.8]	66	[6.4]	1.10	[0.75; 1.61]	.635
16	31 438	[5.6]	43	[4.2]	0.74	[0.48; 1.13]	.158
17	32 348	[5.8]	50	[4.8]	0.83	[0.55; 1.25]	.381
18	31 527	[5.6]	67	[6.5]	1.15	[0.78; 1.68]	.486
19	31 932	[5.7]	60	[5.8]	1.01	[0.68; 1.50]	.948
20	31 237	[5.6]	69	[6.7]	1.19	[0.81; 1.74]	.369
21	31 165	[5.6]	65	[6.3]	1.12	[0.76; 1.65]	.551
22	29 540	[5.3]	42	[4.1]	0.77	[0.50; 1.17]	.221
23	27 429	[4.9]	61	[5.9]	1.20	[0.81; 1.77]	.362
Order month, *n* (%)							
Jan	43 238	[7.7]	77	[7.5]	1.00	[base]	
Feb	41 955	[7.5]	84	[8.1]	1.12	[0.82; 1.53]	.458
Mar	46 893	[8.4]	108	[10.5]	1.29	[0.97; 1.73]	.085
Apr	45 034	[8.0]	70	[6.8]	0.87	[0.63; 1.21]	.411
May	46 168	[8.2]	94	[9.1]	1.14	[0.85; 1.55]	.384
Jun	47 941	[8.6]	80	[7.8]	0.94	[0.69; 1.28]	.684
Jul	49 450	[8.8]	86	[8.3]	0.98	[0.72; 1.33]	.880
Aug	50 321	[9.0]	88	[8.5]	0.98	[0.72; 1.33]	.907
Sep	47 013	[8.4]	98	[9.5]	1.17	[0.87; 1.58]	.302
Oct	46 773	[8.4]	81	[7.9]	0.97	[0.71; 1.33]	.861
Nov	46 098	[8.2]	79	[7.7]	0.96	[0.70; 1.32]	.811
Dec	49 184	[8.8]	86	[8.3]	0.98	[0.72; 1.34]	.907

Abbreviation: RAR, retract-and-reorder.

Table 3. Differences and similarities between RaR- and non-RaR pairs.

	Non-RAR (total number $n = 10\ 310$)		RAR (total number $n = 1031$)		OR [95% CI]		*P*
Age difference >10y							
No	2818	[27.3]	296	[28.7]	1	[base]	
Yes	7492	[72.7]	735	[71.3]	0.93	[0.81; 1.08]	.341
Sex, *n* (%)							
Sexes different	5127	[49.7]	455	[44.1]	1	[base]	
Sexes equal	5183	[50.3]	576	[55.9]	1.26	[1.10; 1.43]	*.001*
					Coef. [95% CI]		
Age difference (y)[a]	21	[9; 36]	21	[9; 34]	−1.00	[−2.04; 0.04]	.059
Similarity of first name[a,b]	6	[5; 8]	6	[5; 8]	−0.06	[−0.19; 0.07]	.348
Similarity of last name[a,b]	7	[6; 9]	7	[6; 9]	−0.15	[−0.29; 0.00]	.043
Similarity of date of birth[a,b]	5	[4; 5]	5	[4; 5]	−0.03	[−0.10; 0.03]	.289
Exam room proximity[a]	4	[2; 6]	3	[2; 6]	−0.62	[−0.77; −0.46]	*<.001*

Abbreviation: RAR, retract-and-reorder.
[a] Med (IQR).
[b] Similarity obtained through Levenshtein algorithm.

infusion by the ambulance service. The resulting retraction may have coincided with the correct order of normal saline infusion for patient *B*, which is factually completely unrelated.

Recognizing an ordering error and retracting it is a sign of awareness and professional demeanor. However, this vigilant performance may be negatively affected by stress and high

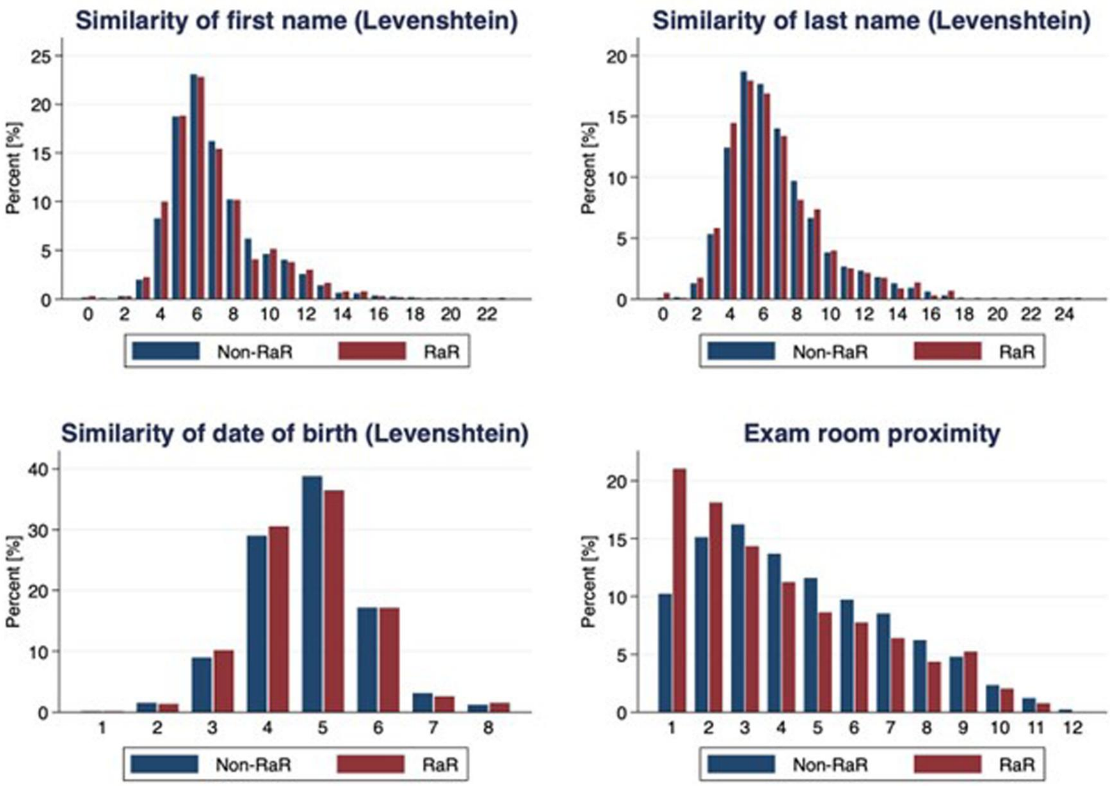

Figure 4. Similarity of (A) first name, (B) last name, (C) birthdate, and (D) exam room proximity in RaR- and non-RaR pairs. RAR, retract-and-reorder.

cognitive workload. High cognitive workload may be associated with both, a higher risk for wrong-patient orders *and* less performance in detecting them. Thus, indicators of staff workload as tested in our study may be predictive for nonintercepted wrong-patient ordering errors, but not RaR events. Interviews with clinicians reveal that cognitive factors are frequently reported as contributing factors to voided, wrong-patient orders.[30] However, we did not comprehensively assess the health care professional's workload at the time of the order. We assumed that fatigue would increase during the HCP's shift. Levin et al[27] have suggested concepts such as "ordering intensity" and a "work block score" as proxy measure for workload and physician fatigue, respectively, which may have been more appropriate.

Conclusions

Our study adds to the evidence that insufficient user interface design in an electronic ordering system within an EMR can have detrimental effects on patient safety.[32–35]

As reported by others, we found EMR usability issues to be a main contributor to wrong-patient order events (in this study, RaR events). We believe that the design of the dashboard and order entry screen of our EMR and the slow speed of system responses lead to inattentive clicking, resulting in the wrong patient chart being selected for ordering. However, we do not know whether the *actual* proximity of the exam rooms in the ED is the underlying factor and not the representation on the screen. Comparative studies using different EMRs would be needed to elicit this.

Retract-and-reorder events are a subset of all wrong-patient ordering errors, but of unknown proportional share. As the likelihood of placing and retracting a wrong order are both affected by cognitive capacity and workload, changes in EMR usability may increase wrong-patient orders and reduce RaR events simultaneously by increasing cognitive demands and workflow blocks. To shed more light on RaR events in EDs, future research is required focusing the relation between intercepted and non-intercepted wrong-patient orders. In addition, further studies involving multiple EDs with more extensive data collection, for example, concerning the workload and qualification of the involved health care professionals would be needed to evaluate the contributing factors to medication errors. As our hospital system will switch to a new EMR in 2024, we are planning to conduct a follow-up study comparing the two systems.

Acknowledgments

None declared.

Author contributions

Gert Krummrey, Martin Müller, and David L.B. Schwappach wrote the manuscript with additional support by all authors (Writing - original draft and review & editing). Gert Krummrey performed the data curation. Martin Müller performed the formal analysis. All authors conceived the study (Conceptualization).

Funding

W.E.H. has received research funding from the European Union, the Swiss National Science Foundation, Zoll

Foundation, Dräger Medical, Germany, Mundipharma Research, United Kingdom, MDI International, Australia, Roche Diagnostics, Germany, all outside the submitted work. W.E.H. has provided paid consultancies to AO Foundation, Switzerland, MDI International, Australia, and SIWF, all outside the submitted work. W.E.H. has received financial support for a congress he chaired from EBSCO, Germany, Isabel Healthcare, UK, Mundipharma Medical, Switzerland, VisualDx, United States, all outside the submitted work. M.M. has been funded by the Bangerter Foundation and the Swiss Academy of Medical Sciences through the "Young Talents in Clinical Research" (grant TCR 14/17) as well with an in-house grant of the Clinical Trial Unit, and the Swiss Federal Department of Defence, Civil Protection and Sport. M.M. received research funding from Swiss Heart Foundation Research Grant, International Emergency Care Foundation Grant, and Summer-School on Refugee and Migrant Health—research grant from Burgergemeinde, all outside the submitted work.

Conflict of interest

All other authors report no conflict of interest.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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JAMIA Open, 2024, 7, 1–10
https://doi.org/10.1093/jamiaopen/ooae103
Research and Applications