

Evaluation of Medication Errors at the Transition of Care From an ICU to Non-ICU Location

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Objectives: To determine the point prevalence of medication errors at the time of transition of care from an ICU to non-ICU location and assess error types and risk factors for medication errors during transition of care.

Design: This was a multicenter, retrospective, 7-day point prevalence study.

Setting: Fifty-eight ICUs within 34 institutions in the United States and two in the Netherlands.

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Patients: Nine-hundred eighty-five patients transferred from an ICU to non-ICU location.

Interventions: None.

Measurements and Main Results: Of 985 patients transferred, 450 (45.7%) had a medication error occur during transition of care. Among patients with a medication error, an average of 1.88 errors per patient (sd, 1.30; range, 1–9) occurred. The most common types of errors were continuation of medication with ICU-only indication (28.4%), untreated condition (19.4%), and pharmacotherapy without indication (11.9%). Seventy-five percent of errors reached the patient but did not cause harm. The occurrence of errors varied by type and size of institution and ICU. Renal replacement therapy during ICU stay and number of medications ordered following transfer were identified as factors associated with occurrence of error (odds ratio, 2.93; 95% CI, 1.42–6.05; odds ratio 1.08, 95% CI, 1.02–1.14, respectively). Orders for anti-infective (odds ratio, 1.66; 95% CI, 1.19–2.32), hematologic agents (1.75; 95% CI, 1.17–2.62), and IV fluids, electrolytes, or diuretics (odds ratio, 1.73; 95% CI, 1.21–2.48) at transition of care were associated with an increased odds of error. Factors associated with decreased odds of error included daily patient care rounds in the ICU (odds ratio, 0.15; 95% CI, 0.07–0.34) and orders discontinued and rewritten at the time of transfer from the ICU (odds ratio, 0.36; 95% CI, 0.17–0.73).

Conclusions: Nearly half of patients experienced medication errors at the time of transition of care from an ICU to non-ICU location. Most errors reached the patient but did not cause harm. This study identified risk factors upon which risk mitigation strategies should be focused. (*Crit Care Med* 2019; 47:543–549)

Key Words: adverse drug event; critical care; intensive care; medication error; medication safety; transition of care

Medication errors that occur during the transition of care (TOC) from an inpatient hospitalization to the outpatient setting are frequent and well described, occurring in between 60% and 90% of discharged patients (1–5). However, medication errors during the TOC from the ICU to a lower acuity setting within the hospital are not well characterized. ICU patients are particularly vulnerable to medication errors for many reasons, including

the frequent use of high-risk medications, altered end-organ function, and inability or reduced ability to participate in their own care (6, 7).

Inadvertent continuation of newly initiated medications indicated for ICU-specific conditions or preventative measures can lead to patients receiving unnecessary medication prescriptions at hospital discharge (8–16). In addition to new medications started in the ICU, chronic medications may be held, doses may be changed, and interactions between chronic and newly started medications may occur (1, 17).

Risk factors associated with medication errors during transfer out of the ICU to a lower acuity setting within the same institution have not been described. It is unknown whether medication- or patient-specific factors are associated with medication errors at this TOC or whether there are systems of care or best practices associated with a decreased risk of medication error during TOC from the ICU. The purpose of this study was to describe the point prevalence of medication errors during the TOC from an ICU to lower acuity setting within an institution, describe the types of errors that occur, and explore patient-, medication-, and system-related factors that are associated with medication errors in this population.

MATERIALS AND METHODS

Study Design and Site Selection

This was a multicenter, retrospective, observational, 7-day point prevalence study. Pharmacists were recruited via email communication to participate in data collection. Institutional review board approval was obtained at all participating sites prior to commencement, and The Johns Hopkins Hospital served as the coordinating site. All participating pharmacists were required to attend a conference call for training on the data collection form and appropriate study variable definitions to ensure consistency and reliability among investigators. All data were collected retrospectively for the same 7-day study period at all sites. The principal investigator (R.M.K.) was available for questions during data collection, which commenced on or after August 21, 2016, and was completed by July 10, 2017.

The participating pharmacists collected and recorded deidentified data in a secure, web-based application (REDCap 7.6.9, Vanderbilt University, Nashville, TN) that was developed and maintained by The Johns Hopkins University School of Public Health.

Patient Population

Patients were identified through evaluation of daily ICU census reports during the 7-day study period between August 14, 2016, at 00:00 and August 20, 2016, at 23:59. Patients transferred from an ICU to a non-ICU location within the same institution were included. If multiple transfers occurred for the same patient during this time period, only the first transfer of each patient was assessed.

Evaluation of Medication Errors

Each active medication order within 1-hour pre- and post-ICU transfer was evaluated for the potential of a medication error. Medications prior to transfer were defined as active medication orders in the ICU within 1 hour prior to transfer to a lower level of care and medications after transfer were defined as active medication orders in the lower level of care at 1 hour after transfer from the ICU. Scheduled and as needed medications were included except for keep vein open IV fluids, saline flushes, and as needed medication orders written in case of medical emergency. Medication orders that were discontinued prior to administration were not evaluated.

A medication error was recorded if any of the following were true: 1) no indication (a medication was ordered without a clear indication); 2) untreated condition (a medication should have been ordered but was not); 3) incorrect therapeutic interchange (errors stemming from a therapeutic interchange to a formulary agent); 4) ICU-specific indication (e.g., stress ulcer prophylaxis, treatment of ICU delirium); 5) incorrect or inappropriate dose, frequency, or time of administration; 6) inappropriate duration of therapy; 7) therapeutic duplication; 8) drug-drug interaction (considered contraindicated or dose adjustment recommended); 9) drug monitoring (incorrectly timed or omitted on transfer); and 10) other (as determined by the clinical judgment of the pharmacist). Pharmacists collecting data used clinical judgment to determine the presence of error by reviewing the electronic health record, written handoffs between pharmacists, and the home medication list. To minimize variability, a document defining each type of medication error was distributed to all data collectors. Recorded errors were classified as “A” through “I” based upon the National Coordinating Council (NCC) for Medication Error Reporting and Prevention (MERP) Index for Categorizing Medication Errors (18).

Outcome Measures

The primary outcome was the point prevalence of medication errors occurring during the TOC from an ICU to non-ICU location within the same institution. Secondary outcomes were types of errors and their severity. Independent risk factors for medication error at ICU TOC are also reported.

Statistical Analysis

Descriptive statistics were used to describe prevalence of medication error and characteristics of the errors. Bivariate analyses were conducted where each medication-, patient-, ICU-, and institution-level characteristic was compared between patients who were found to have at least one medication error during TOC and those who did not; chi-square or Fisher exact test was used for categorical variables and Student *t*, or Mann-Whitney *U* tests were used for continuous variables, as appropriate. Variables with a *p* value of less than 0.05 in these bivariate analyses were considered for inclusion in a multivariate logistic regression model to determine independent risk factors for medication errors on TOC. Two variables, admission diagnosis and ICU design, were chosen not to be included in the

multivariate logistic regression model due to risk of overfitting the model and potential collinearity with admitting unit and providers writing orders for patients in the ICU, respectively. Medication orders written by multiple provider groups in the ICU were analyzed together compared with medication orders written by only one provider group. Statistical analyses were conducted using Stata 14.1 (StataCorp, College Station, TX).

RESULTS

Demographics

Patients were included from 58 ICUs within 34 institutions in the United States and two in the Netherlands (Table 1). All ICUs had a dedicated clinical pharmacist. A minority of ICUs had formal policies or guidelines for TOC (32.8%) or had electronic health records allowing communication internally between pharmacists (41.4%) or between pharmacists and healthcare team members (34.5%).

Point Prevalence of Medication Errors and Types of Errors

Of the 985 patients transferred from an ICU to a non-ICU location during the study period, 450 patients (45.7%) had at least one medication error occur during TOC. Among patients with a medication error, the mean number of errors per patient was 1.88 (SD, 1.30; range, 1–9), with most patients (55.1%) experiencing one error (Fig. 1). The medication classes with the greatest prevalence of errors were gastrointestinal (21.6%), cardiovascular (14.5%), and pain (11.0%) (Table 2). Some medication errors were identified as having multiple error types. The three most common types of errors were continuation of medication with an ICU-specific indication (28.4%), untreated condition (19.4%), and medication with no clear indication upon investigator review (11.9%) (Table 2). Of the 239 errors classified as medications with an ICU-specific indication, medications for stress ulcer prophylaxis (histamine H₂ receptor antagonists and proton pump inhibitors [PPIs]) accounted for 88 errors (36.8%) and antipsychotics accounted for 24 errors (10.0%). Of the 163 errors (19.4%) classified as untreated conditions, the drug classes associated with the majority of these errors were cardiovascular ($n = 45/163$ [27.6%]) and neurologic agents ($n = 21/163$ [12.9%]).

Most errors (94.2%) were NCC MERP category D or below (did not cause patient harm) (Table 3). Only 49 of the 842 (5.8%) errors assessed were categorized as harmful (NCC MERP category E-H). The most common types of errors associated with harm were incorrect dose ($n = 12/53$ [22.6%]) and untreated condition ($n = 10/53$ [18.9%]). The medication classes most commonly categorized as harmful were anti-infective ($n = 14/49$ [28.6%]), cardiovascular ($n = 9/49$ [18.4%]), and neurologic ($n = 6/49$ [12.2%]).

Risk Factors for Medication Errors

Results of the multivariate logistic regression are presented in Supplemental Table 1 (Supplemental Digital Content 1, <http://links.lww.com/CCM/E328>). In the multivariate logistic

TABLE 1. ICU Characteristics ($n = 58$)

Characteristic, n (%)	ICUs ($n = 58$)
Type of institution	
Community nonteaching	11 (19.0)
Community teaching	13 (22.4)
University	34 (58.6)
Total number of inpatient beds at institution	
100–249	2 (3.4)
250–499	22 (37.9)
500–999	17 (29.3)
> 999	17 (29.3)
Total number of ICU beds at institution	
< 25	7 (12.1)
25–49	11 (19.0)
50–99	18 (31.0)
> 100	22 (37.9)
Admitting ICU	
Medical	13 (22.4)
Mixed medical/surgical	20 (34.5)
Surgical	11 (19.0)
Other	14 (24.1)
Number of ICU beds in transferring ICU	
< 10	6 (10.3)
10–15	16 (27.6)
16–20	15 (25.9)
21–25	12 (20.7)
> 25	9 (15.5)
ICU design	
Closed ^a	12 (20.7)
Open with mandatory intensivist consultation ^b	12 (20.7)
Open without mandatory intensivist consultation ^b	25 (43.1)
Semi-closed ^c	9 (15.5)
Providers writing medication orders for patients in ICU	
ICU team only	13 (22.4)
Multiple services	39 (67.2)
Primary/admitting service only ^d	6 (10.3)
Patient care rounds performed in the ICU ^e	47 (81.0)
Orders discontinued and rewritten at time of transfer from ICU	9 (15.5)
Policy or guideline for transition of care from ICU	19 (32.8)

^aAll patients admitted under an intensivist.

^bAll patients admitted under a nonintensivist.

^cSome patients admitted under an intensivist and some under a nonintensivist.

^dFor open or semi-closed units.

^eRounds on each patient with an intensivist at least 5 days per week.

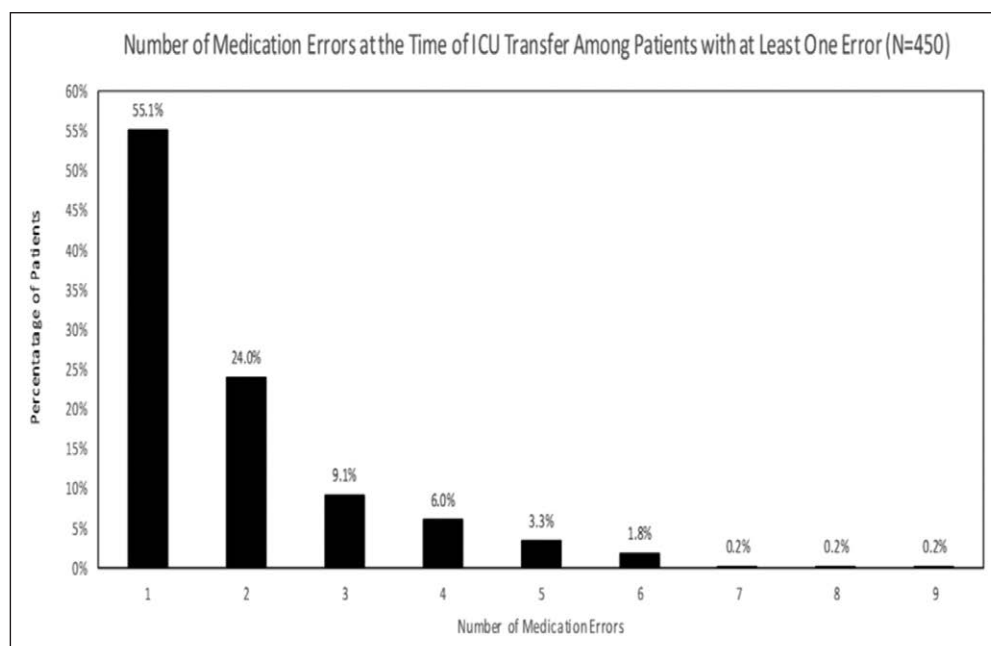


Figure 1. Distribution of errors per patient among patients with at least one error at the time of transition out of the ICU.

regression model, renal replacement therapy during ICU stay and number of medications ordered following TOC were identified as factors independently associated with the occurrence of an error (odds ratio [OR], 2.93; 95% CI, 1.42–6.05; OR, 1.08; 95% CI, 1.02–1.14, respectively). ICU length of stay, mechanical ventilation, and vasopressor use were not associated with an increased risk for error. Orders for anti-infectives (OR, 1.66; 95% CI, 1.19–2.32); hematologic agents (OR, 1.75; 95% CI, 1.17–2.62); and IV fluids, electrolytes, or diuretics (OR, 1.73; 95% CI, 1.21–2.48) at TOC were independently associated with an increased odds of error occurrence. Factors associated with decreased odds of error occurrence in the multivariate logistic regression model were daily patient care rounds in the ICU (OR, 0.15; 95% CI, 0.07–0.34) and orders discontinued and rewritten at TOC from the ICU (OR, 0.36; 95% CI, 0.17–0.73). Time of transfer and day of transfer were not associated with risk for error. Complete results of the univariate analyses are presented in **Supplemental Table 2** (Supplemental Digital Content 2, <http://links.lww.com/CCM/E329>), **Supplemental Table 3** (Supplemental Digital Content 3, <http://links.lww.com/CCM/E330>), **Supplemental Table 4** (Supplemental Digital Content 4, <http://links.lww.com/CCM/E331>), and **Supplemental Table 5** (Supplemental Digital Content 5, <http://links.lww.com/CCM/E332>).

Institution and ICU characteristics associated with error on TOC from the ICU were community teaching hospitals (OR, 3.96; 95% CI, 1.79–8.79) and hospitals with 500–999 total inpatient beds (OR, 4.26; 95% CI, 1.05–17.32). As compared with ICUs with less than or equal to 15 beds, the odds of error in ICUs with 16–20 beds were significantly lower (OR, 0.40; 95% CI, 0.21–0.74) and there was a nonsignificant increase in odds of error in ICUs with greater than 25 beds (OR, 2.06; 95% CI, 0.95–4.48). There was also a trend toward increased odds

of error in institutions with greater than 100 ICU beds as compared with those with less than 25 ICU beds (OR, 3.37; 95% CI, 0.98–11.57). There was no significant difference in the odds of error between ICUs in which the ICU team, primary/admitting service, or multiple services wrote medication orders.

DISCUSSION

This is the first study to evaluate medication errors during TOC from the ICU to a lower acuity inpatient setting. Our findings demonstrate that errors at this critical transition are frequent, although most did not lead to patient harm. During ICU TOC, patients are moved from a setting of inten-

sive care and resources to an environment with less monitoring. A large amount of information needs to be accurately and efficiently conveyed between the discharging and admitting teams. In addition, medication orders must be reconciled to determine the most appropriate medication regimen for the noncritically ill patient.

Errors during TOC out of the ICU were common in this study, with almost half of patients having at least one error. This is similar to the rates of medication errors detected on TOC from the inpatient to outpatient settings in previous studies (2–5). A 2009 study of the impact of a comprehensive medication reconciliation program found pre- and post-intervention discharge medication error rates of 57% and 33% in medical units and 90% and 47% in surgical units, respectively (2). In a study by Schnipper et al (3), 49% of patients had unexplained discrepancies between their preadmission and discharge medication orders. A 2006 study of medication reconciliation-related errors reported to MEDMARX (Quantros, Inc., Milpitas, CA), demonstrated that 66% occurred during transitions between levels of care (19).

Almost 30% of errors identified were related to inappropriate continuation of medications with an ICU-specific indication, and of these, 37% were continuation of agents for stress ulcer prophylaxis. This type of error has the potential to be perpetuated beyond the acute hospitalization, putting patients at risk for long-term side effects. Inappropriate continuation of PPIs after hospitalization has been estimated at 52% to 82% of patients prescribed these agents at discharge (7–12). The long-term use of PPIs has been associated with adverse effects, such as increased risk for fracture, pneumonia, *Clostridium difficile* infection, dementia, and chronic kidney disease (20–27). Inappropriate continuation of antipsychotics for ICU delirium after hospital discharge has been reported in several studies (14–16). We found that antipsychotics accounted for 10% of

TABLE 2. Characteristics of Medication Errors (n = 842)

Characteristic, n (%)	Errors (n = 842)
Medication class	
Anti-infective	68 (8.1)
Bronchorespiratory	31 (3.7)
Cardiovascular	122 (14.5)
Diuretic	5 (0.6)
Electrolyte	66 (7.8)
Endocrine	33 (3.9)
Gastrointestinal	182 (21.6)
Hematologic	50 (5.9)
Immunomodulatory/immunosuppressants	4 (0.5)
IV fluids	9 (1.1)
Neurologic	81 (9.6)
Ophthalmic	6 (0.7)
Pain	93 (11.0)
Topical	43 (5.1)
Urinary	7 (0.8)
Vitamin	8 (1.0)
Other	34 (4.0)
Type of error ^a	
Dose	54 (6.4)
Drug monitoring	12 (1.4)
Drug-drug interaction	8 (1.0)
Duplication	84 (10.0)
Duration	36 (4.3)
Errors related to therapeutic interchange	7 (0.8)
Frequency	10 (1.2)
ICU-only indication	239 (28.4)
Indication and no pharmacotherapy	163 (19.4)
No indication	100 (11.9)
Route of administration	72 (8.6)
Timing	57 (6.8)
Other	43 (5.1)

^aSome medication errors identified as having multiple types of error, n = 883.

the medications with an ICU-specific indication that were inappropriately continued on transfer. These agents also carry long-term risks, including metabolic syndrome and extrapyramidal effects (28, 29). Effective strategies to reduce inappropriate prescribing of these agents include using a standardized approach for initiation and discontinuation of therapy, providing targeted education regarding their appropriate use, and

TABLE 3. Categorization of Error Severity (n = 842)

Severity of Error ^a	Errors, n (%), n = 842
Category A: circumstance with the capacity to cause error	51 (6.1)
Category B: error did not reach the patient	111 (13.2)
Category C: reached the patient, no harm	631 (74.9)
Category D: required monitoring and/or intervention to preclude harm	0
Category E: temporary harm, required intervention	28 (3.3)
Category F: temporary harm, required initial or prolonged hospitalization	15 (1.8)
Category G: permanent patient harm	4 (0.5)
Category H: required intervention necessary to sustain life	2 (0.2)
Category I: contributed to the patient's death	0

^aBased on National Coordinating Council for Medication Error Reporting and Prevention index for categorizing medication errors.

obtaining an accurate home medication list on hospital admission (13, 30–33).

In addition to unnecessary continuation of ICU medications, 19.4% of errors were related to untreated conditions. Although not specifically quantified, some of these errors included failure to resume home medications. A study by Bell et al (1) demonstrated that patients admitted to an ICU had a higher risk of unintentional medication discontinuation compared with non-ICU hospitalized patients and nonhospitalized controls. Additionally, patients who had statins or antiplatelet/anticoagulant agents unintentionally discontinued had a significantly higher rate of the composite endpoint of death, emergency department visit, or emergent hospitalization within 1 year of admission. Reconciliation of medications at the time of ICU transfer can reduce medication errors during this transition (34, 35).

The multivariate logistic regression model demonstrated a number of variables associated with error at TOC from the ICU. Institution and ICU characteristics associated with error included community teaching hospitals and hospitals with 500–999 total inpatient beds. The reasons for these findings are uncertain but may be due to differences in patient acuity, practice models, and resources between different types of institutions. The trend toward increased odds of error in institutions with more total ICU beds and in ICUs with greater than 25 beds may also be related to the availability of resources for this large number of patients (e.g., pharmacist to patient ratio). Additionally, mixed ICUs were found to have greater odds of error on TOC, potentially due to the heterogeneity of this population, providing an additional complexity in standardizing TOC practices.

Patient characteristics associated with error included renal replacement therapy and number of medications ordered at

TOC. Patients receiving renal replacement therapy in the ICU may require frequent medication dosage adjustments as renal replacement modalities are changed or renal function recovers, which may predispose them to errors.

The two factors associated with reduced odds of medication error during TOC were daily patient care rounds and discontinuation/reordering medications on transfer. Performing daily patient care rounds in the ICU has consistently been associated with improved communication, reduction in harm, and better patient outcomes, including decreased ICU length of stay and mortality (36). This study highlights the importance of interdisciplinary rounds and the pharmacist's involvement on these rounds in the ICU. Discontinuation and reordering of medications at TOC was uncommon, only occurring in nine of the 58 ICUs included in the study. Although this additional step in the transfer process may require more resources, the associated reduction in medication errors may prove cost-effective. Further studies are needed to identify best practices with regards to the ICU transfer medication reconciliation process.

There were several limitations to this study. First, we could not control for potential interrater variability in reporting medication errors, however, we attempted to systematically eliminate variability by providing definitions for each variable collected and discussing these with all investigators. We also cannot exclude the possibility of variation in self-reporting of errors. Active medication orders within 1 hour of TOC from the ICU were assessed for error. As such, prescribing errors that were corrected prior to order verification or medication administration may not have been captured. Dispensing and administration errors not documented in the medication administration record were not evaluated in this study, suggesting that the true error rate is likely higher than reported. It is unknown whether the errors reported in this study were collected internally at each institution via error reporting software by other noninvestigator clinicians. It is also unknown how long these errors persist, as they could have been corrected after the immediate transition period. The presence of an error was determined by retrospective review of the electronic health record, so it is possible that errors were miscategorized if data were missing or incorrectly documented.

Data regarding pharmacy practice models and ICU staffing models were not collected. The contribution of pharmacy and ICU staffing models to errors at TOC out of the ICU warrants further study. Similarly, the role of the ICU pharmacist in preventing these errors cannot be elucidated from this study as all reporting ICUs had a dedicated pharmacist.

CONCLUSIONS

Nearly half of patients experience medication errors at the time of TOC from an ICU to non-ICU location within the same institution. Most errors reached the patient but did not cause significant harm. Risk factors for error at ICU TOC included renal replacement therapy in the ICU, number of medications at TOC, and orders for anti-infective, hematologic medications, and IV fluids/electrolytes/diuretics. Medication

error mitigation strategies should focus on these high-risk patients. Daily patient care rounds in the ICU and discontinuation/reordering of medications at TOC were associated with lower odds of error. Other findings such as higher odds of error in community teaching hospitals and hospitals with 500–999 inpatient beds and lower odds of error in ICUs with 16–20 beds are hypothesis-generating and warrant further investigation.

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