The Critical Care Safety Study: The incidence and nature of adverse events and serious medical errors in intensive care*

Jeffrey M. Rothschild, MD, MPH; Christopher P. Landrigan, MD, MPH; John W. Cronin, MD; Rainu Kaushal, MD, MPH; Steven W. Lockley, PhD; Elisabeth Burdick, MS; Peter H. Stone, MD; Craig M. Lilly, MD; Joel T. Katz, MD; Charles A. Czeisler, PhD, MD; David W. Bates, MD, MSc

Objective: **Critically ill patients require high-intensity care and may be at especially high risk of iatrogenic injury because they are severely ill. We sought to study the incidence and nature of adverse events and serious errors in the critical care setting.**

Design: **We conducted a prospective 1-year observational study. Incidents were collected with use of a multifaceted approach including direct continuous observation. Two physicians independently assessed incident type, severity, and preventability as well as systems-related and individual performance failures.**

Setting: **Academic, tertiary-care urban hospital.**

Patients: **Medical intensive care unit and coronary care unit patients.**

Interventions: **None.**

Measurements and Main Results: **The primary outcomes of interest were the incidence and rates of adverse events and serious errors per 1000 patient-days. A total of 391 patients with 420 unit admissions were studied during 1490 patient-days. We found 120 adverse events in 79 patients (20.2%), including 66 (55%) nonpreventable and 54 (45%) preventable adverse events as well as 223 serious errors. The rates per 1000 patient-days for all adverse events, preventable adverse events, and serious errors were 80.5, 36.2, and 149.7, respectively. Among adverse events, 13% (16/120) were life-threatening or fatal; and among serious errors, 11% (24/223) were potentially life-threatening. Most serious medical errors occurred during the ordering or execution of treatments, especially medications (61%; 170/277). Performance level failures were most commonly slips and lapses (53%; 148/277), rather than rule-based or knowledge-based mistakes.**

Conclusions: **Adverse events and serious errors involving critically ill patients were common and often potentially life-threatening. Although many types of errors were identified, failure to carry out intended treatment correctly was the leading category. (Crit Care Med 2005; 33:1694–1700)**

Key Words: patient safety; adverse events; medical errors; critical care; intensive care unit; human factors

The Institute of Medicine's 1999 groundbreaking report "To Err Is Human" estimated that medical errors cause 44,000–98,000 deaths each year (1). Although controversy (2, 3) surrounds the mortality estimates, it is evident that medical errors and accidental injuries occur too frequently. To improve safety, the complex healthcare structure, including processes at the systems level (administrators, supervisors, equipment designers) and individual performance factors at the point of care, must be better understood (4).

Critical care presents substantial patient safety challenges. It is fast-paced, is complex, and commonly requires urgent high-risk decision-making, often with incomplete data and by physicians with varying levels of critical care training. These factors may lead to higher medical error rates than elsewhere (5). Moreover, critically ill patients may be particularly vulnerable to iatrogenic injury because of the severity and instability of their illness and their frequent need for high-risk interventions and medications (6).

To better understand the incidence and nature of serious medical errors in critical care settings, including coronary care, we conducted a multidisciplinary epidemiologic study to describe the frequency and types of adverse events and near-misses and to identify potential prevention strategies.

MATERIALS AND METHODS

The Critical Care Safety Study was conducted as part of the Harvard Work Hours and Health Study from July 2002 to June 2003,

***See also p. 1860**.

From the Divisions of General Internal Medicine (JMR, RK, EB, DWB), Sleep Medicine (CPL, JWC, SWL, CAC), Pulmonary and Critical Care Medicine (JWC, CML), Cardiology (PHS), and Infectious Disease (JTK), Department of Medicine, Brigham and Women's Hospital, Harvard Medical School; Division of General Pediatrics, Department of Medicine (CPL), Childrens Hospital, Harvard Medical School; and Division of Sleep Medicine (CPL, JWC, SWL, CAC), Harvard Medical School, Boston, MA.

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assessing the effects of intern sleep deprivation on patient safety (7). Data for the current study were collected during nine 3-wk intern rotation periods equally distributed throughout the 12 months. Interns rotated in the medical intensive care unit (MICU) and coronary care unit (CCU) and maintained the traditional schedule of working overnight every third night. The study was performed with the approval of the institutional human subjects review board.

Study Site and Patient Population. The study occurred in the MICU and CCU of a 720-bed tertiary care academic hospital. Both ten-bed units care only for adult patients and have a closed attending model (8), with hospital-based intensivists and cardiologists assuming primary patient responsibility. Attending physicians were routinely present in the units from 7 am to 7 pm and other times for emergencies. Patients on non-MICU/CCU services boarded in these units and patients whose length of stay was <4 hrs were excluded.

Definitions. The definitions used in this study are provided in Table 1. In contrast to the Harvard Medical Practice Study, (9) our definition of adverse event did not require prolongation of hospitalization or disability on discharge. *Serious medical errors* included preventable adverse events, intercepted serious errors, and nonintercepted serious errors (7). Medication-related adverse events or *adverse drug events* (ADEs) were injuries due to a drug (10).

Study Design and Data Collection. Patients admitted to the MICU or CCU during the observation periods were followed until transfer, unit discharge, or death. All staff and patient-related data were confidential. A four-pronged approach was used to capture suspected adverse events and serious errors (collectively referred to as incidents).

The primary method of data collection was the direct continuous observation method described by Barker (11) and used in prior ICU error studies (12). Barker has previously demonstrated that following the initial few hours of direct observation, there is negligible if any Hawthorne effect (11). Researchers experienced in direct observation and intensivists trained a team of six research-physician observers to detect incidents, and they followed the on-call interns continuously, day and night.

The on-call intern was responsible for new admissions and for the entire unit overnight and under the supervision of an upper-level resident. Observed activities of interest included physical examinations, physician order entry, teaching and work rounds, diagnostic interpretations of test results, and medical procedures, including compliance with sterile technique. Interns entered routine orders both during and after team rounds.

The research observers initially entered suspected incidents into a semistructured confidential diary and then into standardized data forms. If the observer detected an ongoing potentially harmful error unknown to the clinical staff, observers were trained to promptly alert the staff, although these were very uncommon. Observers were trained to capture potential incidents using consistent and objective techniques (11). Interrater reliability testing for observers consisted of 10 patient-days of dual direct and independent observation. The interobserver percent agreement for the occurrence of a serious medical error was 82%.

Voluntary and solicited reports were the second method of incident identification (10). Anonymous, confidential incident reporting forms, available in paper and electronic formats, could be completed by any unit staff member. Formal institutional incident reports and pharmacy incident reports were also reviewed. The third data collection method was a computerized ADE detection monitor (13). The final incident identification method was guided implicit chart abstraction (9) by trained research nurses with critical care experience. Duplicate incident reports were deleted.

Incident Classification. Methods employed to rate incidents were based on techniques used in our previous work (10). Incidents were collected for the entire unit and not restricted to incidents involving the on-call intern, although data on interns were somewhat more comprehensive because of the presence of the observers. The on-call intern was selected for direct observation, as he or she was involved in most important ongoing patient care activities. Two of four physician investigators (JMR, CPL, JWC, RK) independently classified each incident. Incidents not rated as adverse events or serious errors were excluded. For example, a pneumothorax in a patient with severe acute respiratory distress syndrome was excluded if it was judged to have occurred as a result of the underlying disease process, rather than as a consequence of therapy. On the other hand, a pneumothorax immediately following a central venous catheter insertion was rated as an adverse event. Physician raters judged severity on a four-point Likert scale (significant, severe, life-threatening, fatal) and preventability on a five-point Likert scale (prevented, definitely preventable, probably preventable, probably not preventable, definitely not preventable), with the preventability scale collapsed to preventable or not preventable before analysis. Rater disagreements were resolved by discussion.

Medical errors were classified according to clinical activity, including prevention, diagnosis, treatment, procedures, monitoring, and communicating clinical information. Errors were further classified according to the associated individual and systems factors and the behavioral performance class or type (14, 15). Performance errors were classified as skill-based errors (failure to carry out intended plans of action, including slips or unintended acts and lapses or omitted acts), rule-based mistakes (such as using an incorrect treatment protocol), and knowledge-based mistakes (16–18).

Statistical Analysis. Categorical variables in the MICU and CCU were compared with Fisher's exact test. Comparisons of nonnormally distributed continuous variables were made with the Wilcoxon's rank-sum test. Comparisons of means of normally distributed

Table 1. Study definitions

Term	Definition
Medical error	Failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim.
Serious medical error	A medical error that causes harm (or injury) or has the potential to cause harm. Includes preventable adverse events, intercepted serious errors, and nonintercepted serious errors. Does not include trivial errors with little or no potential for harm or nonpreventable adverse events.
Intercepted serious error	A serious medical error that is caught before reaching the patient.
Nonintercepted serious error	A serious medical error that is not caught and therefore reaches the patient but because of good fortune or because the patient had sufficient reserves to buffer the error, it did not cause clinically detectable harm.
Adverse event	Any injury due to medical management, rather than the underlying disease. Examples of an injury would be a rash caused by an antibiotic, deep vein thrombosis following accidental omission to continue prophylactic subcutaneous heparin orders on transfer to the critical care unit, and ventricular tachycardia due to placement of a central venous catheter tip in the right ventricle.
Nonpreventable adverse event	Unavoidable injury due to appropriate medical care.
Preventable adverse event	Injury due to a nonintercepted serious error in medical care.

continuous variables were made with Student's *t*-test. Rates of incidents in the MICU and CCU were compared by means of the binomial test. Individual incidents could be associated with multiple systems and/or cognitive stage errors, such that total percentages could exceed 100. Prediscussion interrater judgments were compared for level of agreement with use of the κ statistic for incident classification (.90), preventability (.80), and severity (.54).

RESULTS

Data were collected during nine 3-wk periods, including five in the MICU and four in the CCU. During 189 observation days there were 420 observed admissions and 1490 observed patient-days (Table 2).

Adverse Events and Serious Errors. There were a total of 120 adverse events, at a rate of 80.5 adverse events per 1000 patient-days (Table 3). Among the 79 patients (20.2%) with adverse events, 54 (13.8%) had one adverse event and 25 (6.4%) had multiple adverse events. There were 16 life-threatening or fatal adverse events and 104 significant or severe adverse events (Table 4). The most common adverse events as categorized by organ systems were respiratory (19%), infectious (15%), cardiovascular (12%), and dermatologic and soft tissue (9%). Among all adverse events, 45% were judged preventable.

There were a total of 223 serious errors, at a rate of 149.7 serious errors per 1000 patient-days. Among serious errors, 24 incidents (11%) were judged to be potentially life-threatening. Examples of adverse events and serious errors are provided in Table 5.

Medications were involved in a large proportion of incidents. Among the adverse events, 56 (47%) were due to ADEs, including 19 preventable ADEs and 37 nonpreventable ADEs. Among the serious errors, medications were responsible for 78%. The rates for preventable and potential, or near-miss, ADEs associated with serious errors were 12.8 and 116.8 per 1000 patient-days, respectively. The medication error rates were similar in the MICU and CCU, at 127.8 and 131.5 per 1000 patient-days, respectively ($p = .12$). Medication errors (n = 193) were most commonly associated with treatment (n = 170) but were also associated with prevention (e.g., heparin prophylaxis for thromboembolic disease), diagnosis (e.g., intravenous contrast), and monitoring (e.g., glucose monitoring during insulin infusions). Medication errors were most commonly due to wrong dosage (Table 6). Medication categories most frequently associated with errors were cardiovascular drugs (24%), anticoagulants (20%), and antiinfective agents (13%).

Table 2. Patient demographics

	MICU	CCU	*p* Value
Observed patients, n	198	193	
Observed unit admissions, n	220	200	
Observed patient-days, n	821	669	
Mean age, yr (± SD)	62.7 (±1.2)	66.0 (±1.1)	.04
Male, n (%)	111 (56)	113 (59)	.4
Caucasian, n (%)	127 (64)	155 (84)	.002
Mean daily unit census[a] (± SD)	9.5 (±0.06)	9.0 (±0.08)	<.001
Median unit length of stay, days (IQR)	3.5 (7.6)	2 (3.3)	<.001
Charlson score, mean (± SD)	4.8 (±0.3)	3.3 (±0.2)	<.001
APACHE II score,[b] mean (± SD)	19.9 (±0.7)	16.5 (±0.6)	<.001
Died in unit, n (%)	36 (17)	18 (9)	.01
Admission source, n (%)			<.001
Emergency department	89 (40)	42 (21)	
Transfer from floor	92 (42)	45 (23)	
Catheterization lab or operating room	5 (2)	64 (32)	
Other hospital	27 (12)	47 (24)	
Other	7 (3)	2 (1)	
Principal reason for admission to unit, n (%)			<.001
Acute coronary syndrome/MI	3 (2)	97 (49)	
Pulmonary edema/CHF	6 (3)	21 (11)	
Cardiogenic shock	5 (2)	5 (3)	
Dysrhythmias/conduction abnormalities	4 (2)	12 (6)	
Other cardiovascular disease	3 (2)	21 (12)	
Acute respiratory failure	66 (30)	12 (6)	
Acute exacerbation of COPD/asthma	15 (7)	1 (0.5)	
Pneumonia/aspiration pneumonitis	17 (8)	1 (0.5)	
Pulmonary emboli	2 (1)	5 (3)	
Acute gastrointestinal hemorrhage	22 (10)	3 (2)	
Acute pancreatitis	6 (3)	0 (0)	
Sepsis syndrome/septic shock	21 (10)	8 (4)	
Acute renal failure	8 (4)	0 (0)	
Acute neurologic disorder, including stroke	6 (3)	4 (2)	
Anemia	4 (2)	1 (0.5)	
Other	32 (15)	9 (5)	

MICU, medical intensive care unit; CCU, coronary care unit; IQR, interquartile range; APACHE, acute physiology and chronic health evaluation; MI, myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

[a]Mean unit daily census includes patients not included as observed patients; [b]see reference 47.

Incident Discovery. Incidents could be recognized and/or reported by more than one method and included direct observation (62%), chart abstraction (49%), solicited staff incident reporting (15%), pharmacy reports and ADE monitoring (7%), and formal incident reporting (4%). Overall, 23% of events were recognized by more than one method. Adverse events and nonintercepted serious errors were most commonly discovered by the patient's nurse (36%), another physician (27%), clinical pharmacists (12%), or the responsible physician (9%) or during chart review by the study team (11%). The majority of incidents occurred during routine care (91%), with far fewer incidents occurring within 30 mins of admission to the unit (4%) or during an emergency intervention (2%). Intercepted serious errors were most commonly caught by the patient's nurse (42%), another physician (23%), or the pharmacist (17%).

Clinical Activities, Human Factors, and Systems Factors Associated with Errors. Incidents due to errors were most common during treatments and procedures (74.8%), especially during the ordering or execution of medications used for treatment (61.4%; Table 6). Other common errors associated with systems failures were errors in reporting or communicating clinical information (13.7%) and failures to take precautions or to follow protocols in order to prevent accidental injury during preventive or diagnostic activities (10.8%) and treatment or procedure activities (7.9%). Performance level failures were judged as skill-based slips and lapses (53%; 148/277), knowl-

Table 3. Incident frequencies and rates

Incident	No. (Rate)[a] MICU	CCU	All	p Value[b]
Adverse event				
Preventable	34 (41.4)	20 (29.9)	54 (36.2)	.19
Nonpreventable	37 (45.1)	29 (43.3)	66 (44.3)	.55
Either	71 (86.5)	49 (73.2)	120 (80.5)	.13
Noninjurious serious error				
Intercepted	65 (79.2)	68 (101.6)	133 (89.3)	.23
Nonintercepted	53 (64.6)	37 (55.3)	90 (60.4)	.57
Either	118 (143.7)	105 (157.0)	223 (149.7)	.6

MICU, medical intensive care unit; CCU, coronary care unit.
[a]Rate per 1000 patient days; [b]comparing MICU rate *vs.* CCU rate.

Table 4. Incident severity classification

Incident Severity	Adverse events, n (%) Preventable	Nonpreventable	All	Noninjurious Serious Errors, n (%) Intercepted	Nonintercepted	All
Significant	19 (35)	30 (46)	49 (41)	57 (43)	44 (49)	101 (45)
Severe	28 (52)	27 (41)	55 (46)	57 (43)	41 (46)	98 (44)
Life-threatening	5 (9)	9 (14)	14 (12)	19 (14)	5 (6)	24 (11)
Fatal	2 (4)	0 (0)	2 (2)	NA	NA	NA
Total	54	66	120	133	90	223

NA, not applicable.

edge-based mistakes (26%; 73/277), rule-based mistakes (5%; 14/277), or unable to be determined (14%; 38/277).

Procedure-Related Sterility Hazards. Failures in sterile technique were tracked during observation of interventional procedures but were not included as serious errors. Sterility hazards associated with the insertion or replacement of central venous or arterial catheters (n = 173) included an intern's failure to wash hands (51% of procedures); failure to use complete cap, gown, and glove protection (16%); failure to properly use sterile drapes (6%); and sterile field violations (17%).

DISCUSSION

We found that serious medical errors with potential for or actually causing harm were common in critical care settings. Our findings translate into a daily rate of 0.8 adverse events and 1.5 serious errors for a ten-bed critical care unit, consistent with other ICU study findings, suggesting that the problem of accidental injuries in critical care is substantial (6, 19). We found that most of the errors were slips and lapses, i.e., failures to carry out intended plans of action. In general, medicine has focused more on determining what to do than on ensuring that plans are effectively executed (20).

In addition to adverse events, identifying the incidence and epidemiology of serious errors is important for improving safety. These errors did not cause harm either because the patient had sufficient reserve to buffer an error (nonintercepted serious error) or because the error was caught before reaching the patient or before harm developed. Under other conditions, serious errors could cause preventable adverse events and therefore are useful to measure as they provide "free lessons" (21) and can provide insight as to how to improve safety. We found direct observation to be especially valuable in detecting near-misses, as they are far less frequently reported or documented in patient charts than adverse events (22). Our findings also suggest that direct observation could be a valuable data collection tool for an institution's quality improvement program (23).

Preventable adverse events and near-misses were often associated with deficiencies in systems-related factors, which contribute to repeated errors, usually by different clinicians, and are amenable to correction by providing unit-wide or hospital-wide solutions. These findings are consistent with prior inpatient safety work not restricted to critical care settings (15, 24).

Some prior critical care safety studies have identified fewer medical errors than this one (12, 23, 25–28). This difference may have occurred because we used a more comprehensive data collection methodology than several of these studies. In addition, our adverse event definition was more inclusive than that used in the Harvard Medical Practice Study, which was designed to detect injuries associated with negligence (9). Because of their importance for quality improvement, we included injuries that did not necessarily result in prolongation of hospitalization or disability on discharge.

Other critical care safety studies have reported more ICU errors, largely because we collected data only on the subset of errors with potential for harm. In a frequently cited ICU study employing direct observation, medical errors were defined as deviations from standard conduct with or without the potential for harm, excluding medical decision errors (25). They found a mean of 1.7 errors per patient-day, with nearly half committed by the physician staff. In a surgical ICU study, life-threatening adverse events re-

Table 5. Examples of adverse events and serious errors

Event Type	Severity	Event Description and Error Classification
Nonpreventable adverse event	Fatal	Acute renal failure resulting in death following appropriate use of tacrolimus in a patient with graft-versus-host disease after bone marrow transplantation for chronic myelogenous leukemia.[a]
	Life-threatening	Transfusion-related acute lung injury following a red blood cell transfusion in a patient with anemia, syncope, and coronary artery disease.
	Severe	Tonic-clonic seizures during imipenem treatment for pseudomonal pneumonia. The antibiotic dosing was appropriate and the seizures resolved after conversion to a different antibiotic.
Preventable adverse event	Fatal	Fatal septic shock resulting from central venous catheter—related bacteremia in a patient with acute respiratory failure from an exacerbation of COPD. Rule-based procedure error: failure to take precautions or follow protocol to prevent accidental injury.
	Life-threatening	Unresponsiveness, hypopnea, and oxygen desaturation after IV lorazepam followed by IV midazolam for a procedure in a patient with a GI hemorrhage. Reversal with flumazenil prevented the need for intubation. Knowledge-based medication error, associated with inadequate training or supervision.
	Severe	Worsening severe ileus in a patient admitted with an acute coronary syndrome and cellulitis on a fentanyl IV drip inadvertently not discontinued for 2 days following attending physician recommendations to stop the narcotic infusion. Skill-based (slip) medication error: accidental failure to discontinue a medication order.
Nonintercepted serious error	Life-threatening	Patient with an AMI and immediately after coronary artery stenting inadvertently began receiving subcutaneous heparin instead of full-dose IV heparin. Error not recognized for 12 hrs, but no apparent adverse event occurred. Knowledge-based medication error: choosing the wrong route and dose.
	Severe	Order to discontinue IV furosemide drip at 10 mg/hr was inadvertently omitted following recognition of overdiuresis and dehydration in a patient with pneumonia. Error discovered 12 hrs later, after the patient diuresed 3.5 L, but without clinical sequelae. Skill-based (slip) medication error: failure to discontinue a medication.
Intercepted serious error	Life-threatening	Order for IV octreotide at 500 μg/hr was intercepted by pharmacy and corrected to 50 μg/hr for a patient with an acute upper GI hemorrhage from esophageal varices. Skill-based (slip) medication error: wrong dosage due to an extra zero.
	Severe	Intern read the wrong day's chest radiograph for a patient with postoperative pulmonary edema. Intern was later informed that the correct radiograph demonstrated worsening edema and a new infiltrate, and new therapy was instituted. Skill-based (slip) diagnostic and monitoring error due to selecting the wrong test to interpret.

COPD, chronic obstructive pulmonary disease; IV, intravenous; GI, gastrointestinal; AMI, acute myocardial infarction; μg, microgram.

[a]There were no nonpreventable fatal adverse events in this study. The example is taken from a companion study (7) conducted in the same units and using the same incident finding methodology during the data collection period covered in the analysis.

sulting from physician care occurred at a rate of 23 adverse events per 1000 patient-days (28). In two MICU studies, errors were responsible for 13 to 40 adverse events per 1000 patient-days (26, 27). These results are comparable to our study findings. While many of these studies included patients with cardiac diseases, little prior patient safety research has focused on cardiac critical care (29, 30). Overall, we found error rates to be comparable in the CCU and MICU (Table 3).

Assuming the rates we found are representative of critical care in teaching hospitals, we estimate that 148,000 life-threatening intercepted and nonintercepted serious errors occur annually in teaching hospitals, given an estimated average national daily ICU census of 55,000 patients, with 47% of all ICUs in teaching hospitals (31).

Hospital-acquired infections in critically ill patients deserve special mention (32). Catheter-related bloodstream infections were especially hazardous because they contributed to the two fatal adverse events in this study. Although it is often impossible to identify a specific error responsible for an infection, deviations from safe practice standards are associated with higher infection rates (33). Proven interventions to reduce ICU infection rates include hand-hygiene compliance (34), full sterile barrier precaution during catheter insertions (35), and empowering nurses to stop catheter insertion procedures if guideline or sterility violations are observed (36).

Many of the skill-based errors (slips and lapses) found in this study are potentially preventable with information and communication technologies that inform, alert, or remind clinicians of tasks (e.g., ordering medications) and test results needing completion, correction, or confirmation. In addition to technological solutions aimed at detection, skill-based errors are particularly amenable to interventions that reduce inattention failures (17).

In addition to previously established patient safety interventions including computerized physician order entry (37), clinical pharmacists (38, 39), and closed ICU staffing, (8) the study hospital has instituted or planned several new interventions since this study. Examples of these improvements include a redesigned state-of-the-art MICU; a new Web-based incident reporting system; introduction of smart intravenous infusion pumps; (40) bar-coded medication administration; communication-improvement strategies such as structured physician sign-outs and mandatory read-back for telephone orders; and a redesigned housestaff work schedule (7).

Future research in critical care patient safety will need to address the particular challenges of the ICU setting, its patients, and especially its staff. Discrepant attitudes exist between ICU nurses and phy-

Table 6. Systems factors associated with serious medical errors[a]

Clinical Activity	No. (%) Preventable Adverse Events $n = 54$	Intercepted and Nonintercepted Serious Errors $n = 223$	All Serious Medical Errors $n = 277$
Prevention and diagnostic errors			
Failure to take precautions or follow protocol to prevent accidental injury[b]	8 (14.8)	22 (9.9)	30 (10.8)
Medication-related	4	9	13
Premature self-extubations	3	0	3
Avoidable delays in diagnosis	3 (5.6)	10 (4.5)	13 (4.7)
Failure to use indicated tests or act on test results	0 (0)	10 (4.5)	10 (3.6)
Inadequate patient assessment	1 (1.9)	7 (3.1)	8 (2.9)
Other prevention or diagnostic error	1 (1.9)	5 (2.2)	6 (2.2)
Total	13 (24.1)	54 (24.2)	67 (24.2)
Treatment and procedure errors			
Medication error in ordering or execution of treatment[b]	13 (24.1)	157 (70.4)	170 (61.4)
Wrong dosage	7	55	62
Duplicate medication orders	0	21	21
Wrong medication	0	15	15
Failure to discontinue a medication order	1	13	14
Wrong rate or frequency	0	12	12
Wrong route	0	8	8
Omitted medication	1	7	8
Wrong patient	0	8	8
Other medication error during ordering or execution of treatment	4	18	22
Failure to take precautions or follow protocol to prevent accidental injury	17 (31.5)	5 (2.2)	22 (7.9)
Preventable nosocomial infection	14	0	0
Inadequate training or supervision	3 (5.6)	2 (0.9)	5 (1.8)
Inadequate reporting or communication	2 (3.7)	3 (1.3)	5 (1.8)
Avoidable treatment delay	1 (1.9)	2 (0.9)	3 (1.1)
Failure to check equipment or defective equipment	1 (1.9)	0 (0)	1 (0.4)
Other treatment or procedure error	1 (1.9)	0 (0)	1 (0.4)
Total	38 (70.4)	169 (75.8)	207 (74.8)
Monitoring and reporting errors			
Inadequate monitoring system[b]	3 (5.6)	14 (6.3)	17 (6.1)
Medication-related	2	12	14
Inadequate reporting/communication[b]	5 (9.3)	33 (14.8)	38 (13.7)
Wrong patient	1	7	8
Do-not-resuscitate order did not match true code status	1	7	8
Test result	0	5	5
Total	8 (14.8)	47 (21.1)	55 (19.9)

[a]More than one factor may be associated with a serious medical error, with the total exceeding 100%; [b]specific subcategories provided for more frequent systems-related errors.

sicians about teamwork experiences (41), and ICU staffs have difficulty discussing errors (42). Therefore, creating a culture to encourage enhanced communication, such as discussing patient safety issues during ICU rounds and increased incident reporting, may reduce future ICU adverse events (22, 43–45).

This study has several limitations. Our findings may not be generalizable to critical care units with a substantially different mean severity of illness or units with markedly different patient types (e.g., surgical) or different staffing models. In addition, our findings may not be generalizable to nonteaching CCUs or teaching units where interns do not enter the majority of physician orders. Our medication error rates may be lower than found in ICUs without computerized physician order entry or onsite pharmacists; both were present in our units. Finally, incident reporting is highly dependent on institutional and unit cultures (46). Higher rates of reported intercepted serious errors in an ICU may be due to increased safety awareness and successful redundancies or built-in checks to more frequently catch errors and/or a culture supportive of more frequently reporting these errors. (47)

CONCLUSIONS

Critical care settings provide lifesaving care for the sickest patients but are also associated with significant risks for adverse events and serious errors. It will be especially important to "engineer out" slips and lapses, to improve the likelihood that treatment in the ICUs is implemented as intended.

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